Trade-off between service and inventory costs

Rationalizing safety stock settings within NXP Semiconductors

by

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NXP founded by Philips

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Summary

Context

NXP operates in a highly dynamic and globalized semiconductor market. The NXP supply chain control is like it peers in semiconductor business quite complex. To manage the supply chain and to deal with the market characteristics, six so called Business Renewal II objectives were launched as part of the one page strategy. On one hand the BR II objectives target for a lower break-even point and on the other hand it aims for operational excellence. For supply chain management this translates in lower stock targets on one hand and better supply chain performance on the other hand. Because of the existing link between these two objectives, this research will support the inventory management project team within the Global Supply Chain Management Competence Center by providing insights in the dynamics between inventory levels and the perceived service levels. With these insights, reducing inventories in an uncontrolled way will be avoided and customer service will be increased.

Problem formulation

The current tools (supply chain configuration tool and zero based inventory budgeting) within NXP do not give support in making a trade-off between inventory costs and service levels. Hence there is a need to:

1. Support planners in deciding where to place the customer order decoupling point and how much safety stock to keep in all the available stock points in order to support NXP's business in the most effective way.
2. Consider an integral supply chain network for safety stock optimizing instead of optimizing local stock points.
3. Perform a sensitivity analysis on the relation between the (safety) stock settings (translated into costs) and the delivery performance (service) is needed.

Based on these three objectives, in combination with the decision that an off-the-shelf model (SCOpE) will be used for optimizing safety stock settings, the central question can be formulated as follows:

Can SCOpE be used for defining the optimal safety stock settings over the network in reference of customer order behavior and preferences and what are the implications of doing so?

Model testing and improvements made

To find out whether SCOpE can be used in practice, six representative case studies within BL MMS-PM are validated by running the model under the same conditions as the real world system followed by a comparison of the model outcomes (i.e. perceived service) with the actual perceived service (i.e. RLIP%). The month under analysis is May 2007 and the results are as follows:

- Eleven root causes were identified for differences, of which:

- Four root causes were linked to the current processes or current decisions made within NXP. These root causes cannot be solved by increasing or decreasing the safety stock settings but only by correct capacity allocation, management decisions or correct CODP locations.
- Seven root causes were linked to incorrect safety stock settings are divided in relevant and less relevant.
  - The less relevant root causes are the order cancellations and returns, the rounding quantities and the P_2 vs. RLIP measurement. We did not focus on these root causes to increase the validity of SCOpE because the occurrence is low and the effect can be seen as minimal compared to the other root causes (based on planners experience).
  - The relevant root causes are under-FC, over-FC, yield fluctuations and batching. Via a sensitivity analysis we proved that these root causes indeed have an impact on the safety stock settings or the perceived service levels. And therefore it is recommended to focus on these parameters in order to increase the validity of SCOpE. The improvements made are as follows:

Improvement area	Before improvement	After improvement
Yield fluctuations	Incorporated by Ton de Kok separately. No details available.	
Batching	Not incorporated in SCOpE	Incorporate batching by increasing the review period for situations in which the demand during a review period is less than the batch size. When the demand during a review period is taller than the batch size, no excess stock will occur because then MOQ+k*RQ will lead to a batch size that equals the demand (because MOQ>>RQ).
Average demand	The average system forecast over the next 13 weeks is calculated per end-product.	The average is calculated based on the business line forecast because this is the best information available of the future demand at a certain time. The average is calculated over 13 weeks starting 4 weeks from now and per end-product.
Standard deviation	The fluctuations of the forecast through time are calculated.	Based on product/market characteristics a representative CV (stand.dev. divided by the average demand) for an aggregated group of end-products will be used and linked to the business line forecast of a specific end-product to determine its standard deviation. Aggregation is used to overcome the limited data availability within NXP and the highly unstable forecast accuracy.

After extension of SCOpE with these improvements made, the SCOpE results were evaluated again for to the same case studies in the month May 2007. For all cases the model improved by introducing these parameters in the sense that the delta between the actual and the modeled service level decreases. All the introduced parameters make the model more similar to the real supply chain practice. The limited amount of cases evaluated and the short review period considered (May 2007) give too less data to prove this finding fully. To have this prove, optimized inventory levels are implemented in practice after which service levels must be analyzed during the coming months. This will also provide us further insights in the real benefits of using a supply chain optimizer like SCOpE within NXP.

Conclusions

Based on the research done, the following conclusions can be made:

- Based on the case studies performed, SCOpE optimization outcomes indicates that there is a sizable potential to reduce safety stocks while maintaining or increasing service levels.
- Monitoring the optimized safety stock settings in the next coming months is necessary to validate the service levels through time. These settings were implemented for the case studies in September 2007.
- SCOpE completes the available tool set around inventory management in NXP, namely the supply chain configuration tool (SCC) and zero based inventory budgeting tool (ZBIB) and can support basic supply chain modeling decisions (Figure M.1).
- SCOpE does not support the optimal CODP location, although SCOpE is very well suited to evaluate the consequences of given CODP choices.
- The current SCOpE version, is not user-friendly enough for immediate use within a planner environment. The supply chain modeling in SCOpE is complex and data gathering is time consuming.

Besides these main conclusion, several other conclusions can be drawn from this research:

- Safety stock costs are only a minor part of the total inventory levels available within NXP.
- SCOpE calculates optimized safety levels in order to reach the targeted service levels. This does not automatically imply inventory cost reductions.

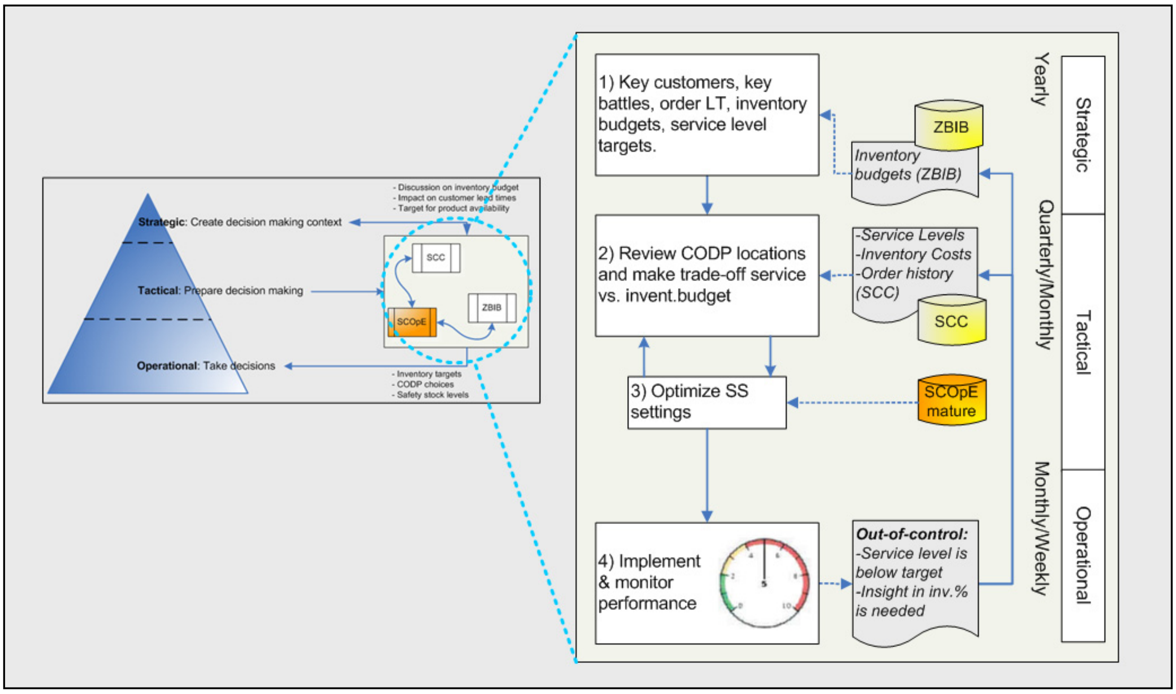

Figure M.1: Placing SCOpE within the current toolset/processes of NXP.

- Before using models in practice and to draw significant correct answers, one must be sure to have sufficient data. If this is not the case, we found that aggregation can be used to overcome this gap.

Recommendations

Based on the research done, five main recommendations can be formulated:

- The current SCOpE version, is not user-friendly enough for immediate use within a planner environment. Hence, four different scenarios are identified and we recommend to go from 1 to 4 in the next coming months in order to reap the benefits of SCOpE:
  - Scenario 1: Use SCOpE and inventory concepts within SCM courses.
  - Scenario 2: Use SCOpE for the definition of guidelines.
  - Scenario 3: Use SCOpE for scenario analysis.
  - Scenario 4: Incorporate SCOpE in the system environment within the SCM organization.
- Do not focus on (solve the) three root causes marked as less relevant within the SCOpE logic, namely order cancellations/returns, rounding quantities and P_2 vs. RLIP measurement. Effort can better be put in the root causes related to the process and decisions made related to inventory (see next recommendation).
- The high inventory levels within NXP are not caused by incorrect safety stock settings but are mainly caused by an over-forecast, increased utilization or a lower planned lead time than expected. Hence, more focus should be on these three issues in order to reduce inventories.
- Monitor the service levels of the pilot projects during the months September, October and November in order to assess whether SCOpE indeed leads to better and more stabilized service levels through time.
- Review the CODP locations on a frequent basis. Currently this is hardly done and therefore the CODP settings within the planning system are not in line with the customer behavior. The result is an inefficient supply chain, too high inventory costs and often a lower service level than expected.

Preface

This thesis is the result of my research on defining the optimal safety stock settings over the network in reference of customer order behavior and preferences and on the corresponding implications. This research project is the final phase of my study Industrial Engineering and Management at the University of Twente in Enschede. For NXP, this thesis contains a methodology on how to be able to make a trade-off between inventory investments and the perceived service levels. Considering inventory and service levels at the same time is new within NXP as well as the end-to-end approach used. For academic reasons this thesis contains an interesting approach about how to deal with mathematical models within a highly fluctuating and unstable practical environment. Moreover, the benefits and limitations of applying theoretical models within practice will become visible.

This thesis is conducted in the period March 2007 till September 2007. The possibilities of performing my research within the Supply Chain Management Competence Center (SCM CC) allowed me to get a good understanding of the supply chain challenges NXP faces. Therefore I would like to thank the members of the SCM CC for their support and the pleasant time I had within this group. Especially I would like to thank Sander Kok for his guidance, support and critical reflections on my work. I learned a lot about how to conduct a research within practice, how to get the right people involved, how to keep on track and how to be a pro-active player within a project team. I would like to thank Erik van Wachem and Ruud Driesen for all the helpful and interesting conversations we have had. Thanks to Peter Luijbregts as well who made it possible to be a graduation student within the SCM CC. Last but not least I would like to thank Bas Kölgen and his whole planning team within the order fulfillment center in Hamburg. We have had great discussions about how to model the NXP supply chains, how to transform the bunch of data into relevant information and how to implement the optimized safety stock settings in practice.
At the university, thanks go out to Leo van der Wegen (UT) and Ton de Kok (TU/e). Their support, guidance, and critical recommendations helped me enormously to fulfill this research. Also the well willingness of Ton to replace Matthieu van der Heijden within the commission is highly appreciated. Finally I would like to thank my parents, brother and sister, girlfriend and friends for standing behind me, being supportive and their outsiders' view on the results obtained during this research.

Mark Roeloffzen
Eindhoven, September 2007.

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Chapter 1 Introduction

Money tied up in inventory can be a significant part of total supply chain management cost. Although, it is generally known that inventories at some locations in the supply chain are unavoidable in order to be able to deliver the right products in the right amounts at the right time to the customer. Hence, reducing inventories in an uncontrolled way will have a direct impact on customer service. This research aims to define the optimal safety stock settings over a network in reference of customer order behavior and preferences. This will not only give support to the planners in order to get insight in the dynamics and optimal settings of safety stocks over a network but also to the inventory management project team to increase insights in inventory management.

The structure of this thesis is depicted in Figure 1.1. A short description per chapter is given as well.

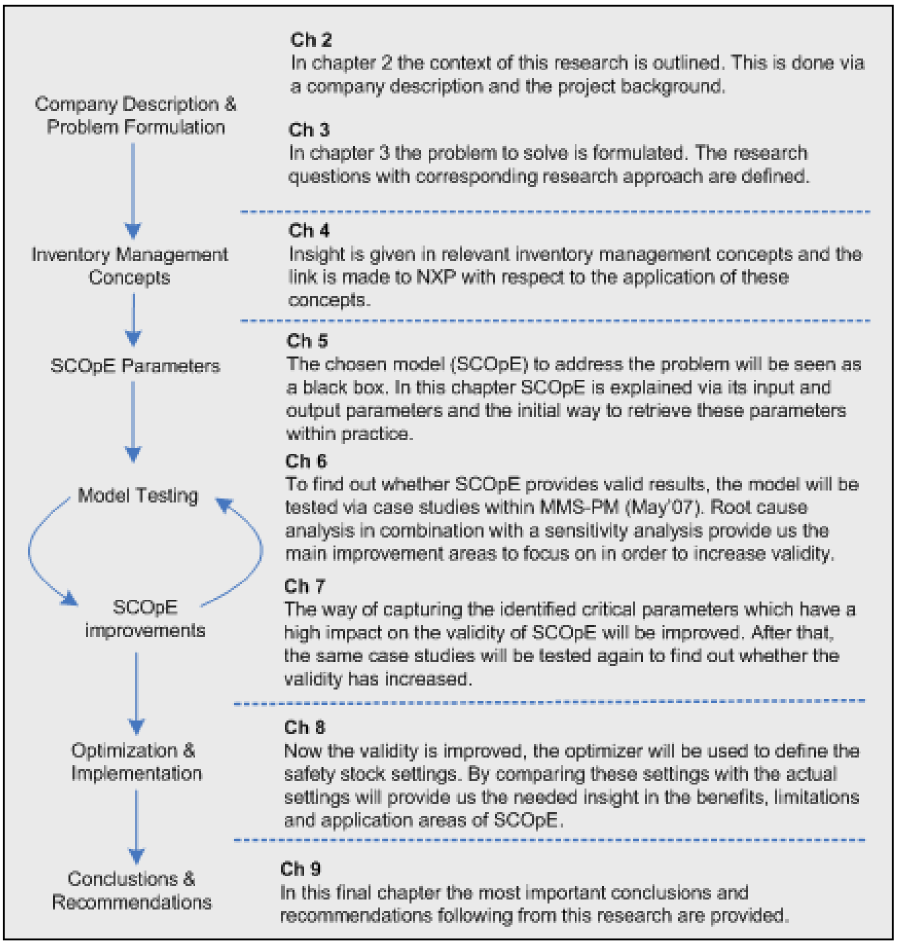


Figure 1.1: Overview of the used research approach

Chapter 2 Company description

The goal of this first chapter is to give a description of the company and the department in which this thesis is conducted. Section 2.1 provides a general company description related to its background, activities, organization structure, product types and customers. Furthermore, insight is given in the supply chain of NXP and some global semiconductor market characteristics. In section 2.2 the reason for performing this research is given. We will close this chapter with a conclusion in section 2.3.

2.1 NXP Semiconductors

This section will give a general description of NXP Semiconductors (in the rest of this thesis referred to as NXP). We will give insight in the background, activities and organization structures (section 2.1.1), as well as in the product types and sales split (section 2.1.2), supply chain structure (section 2.1.3) and finally the semiconductor market characteristics (section 2.1.4).

2.1.1 Background, activities and organization structure

NXP produces semiconductors, system solutions and software in mobile phones, personal media players, TVs, set-top boxes, identification applications, cars and a wide range of other electronic devices. NXP is a former Product Division of Royal Philips Electronics. Since October 1st, 2006, the division Philips Semiconductors changed to NXP Semiconductors. The name change announcement follows an agreement between Royal Philips and Kohlberg Kravis Roberts & Co. (KKR), Bain Capital, Silver Lake Partners, Apax and AlpInvest Partners NV. Within this consortium, Royal Philips still has a 19.9% interest (NXP, 2007a).

NXP is headquartered in Eindhoven (the Netherlands) and has 38,000 employees working in 20 countries across the world with a sales of €4.96 billion (2006) (NXP, 2006a). They are globally ranked ninth and are ranked second within Europe (iSuppli, 2006). The mission of NXP is to become the leader in vibrant media technologies that help engineers and designers develop products that deliver better sensory experiences for consumers.

NXP is divided in business, core and supporting processes as depicted in Figure 2.1.

- **Business processes**
  The business processes are the four business units (BUs), covering their focus areas. These includes Multi Market Systems (MMS), Automotive and Identification (A&I), Home, and Mobile and Personal (M&P). Each BU is responsible for a group of Business Lines (BLs). BLs are responsible for the design and manufacturing of groups of products and form the entrepreneurial entities of the organization. Currently there are 23 BLs which are all profit and loss accountable. Although all of the BLs produce semiconductors, they differ a lot from each other in terms of sales volume, product characteristics and geographical location.

- **Core processes and supporting processes**

  Besides these four business processes, there are four core processes. These are Strategy and Business Development; Innovation & Technology Management; Manufacturing & Integral Supply Chain; and Sales & Marketing. Because of the possibilities for sharing resources between the BLs, some responsibilities are delegated to other entities in the organizations, e.g. the diffusion of wafers and the assembly and test operations are delegated to the core process of manufacturing & Integral Supply Chain (i.e. IC Manufacturing Operation (IMO)[1]) and the sales are delegated to the core process sales & marketing. Finally there are several supporting processes.

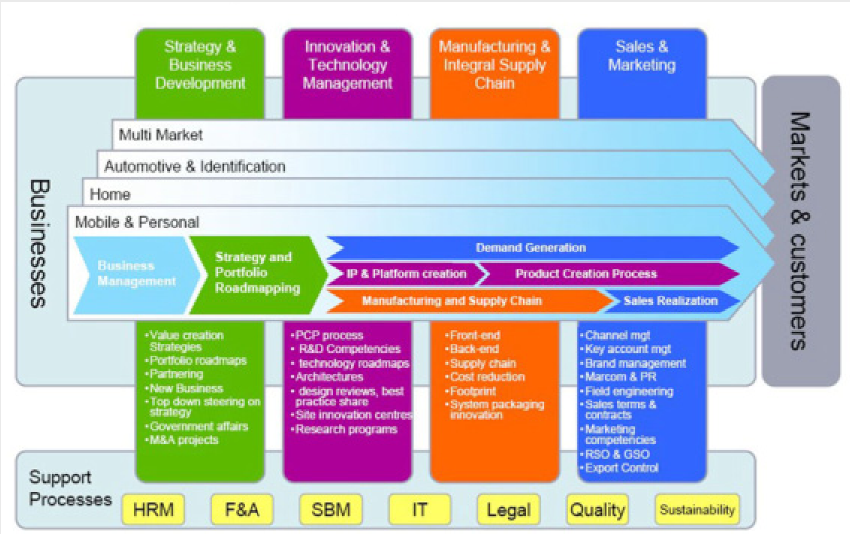


Figure 2.1: The highway to the market (source: NXP intranet, 2007)

This research has been conducted within the Supply Chain Management Competence Center (SCM CC). This SCM CC is a department within the core process Global Supply Chain Management & IT Group. The Global Supply Chain Management & IT Group is on his turn part of the core process IC manufacturing Operation (IMO). A visualization of the organizational structure with the position of the SCM CC is depicted in Appendix A.

2.1.2 Product types and sales split

NXP produces microprocessors. The ones with very complex electronic circuits of transistors, resistors and diodes on it are called Integrated Circuits (ICs) which can be customer specific products or application specific products. The customer specific products are made especially for a customer and will not be sold to other customers, e.g. an IC for Nokia cell phones only produced for Nokia. The application specific products are made for a specific application, e.g. an IC for TV systems can be sold to different customers like LG, Philips or Sony. The ones with only one single function on it are called discretes or commodities which are mainly part of the BU MMS. These products are used in many applications and are bought by many customers. The sales split over the BUs and regions is depicted in Figure 2.2.

[1] *Manufacturing & Integral Supply Chain (Figure 1) is the same as the IC Manufacturing Operation (IMO)*

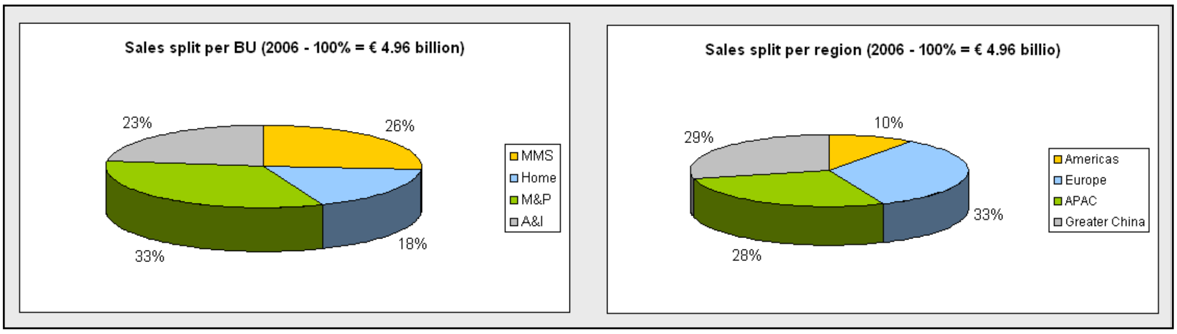


Figure 2.2: NXP sales per BU and per region in 2006 (source: NXP 2007b) (100% = €4.96 billion)

2.1.3 The supply chain of NXP

Semiconductor manufacturing is one of the industries that require most advanced technology (Lee, 2001). Today's semiconductor manufacturing is a complex supply chain consisting of wafer fabrication facilities, assembly and test facilities, warehouses, and distribution centers which are all distributed throughout the world. Figure 2.3 shows the global supply chain of NXP with all the production steps. The production of ICs and discretes/commodities is done in batches because of technical and efficient loading reasons. There are two main processes related to this supply chain labeled as front-end and back-end. Within the front-end, wafers are produced that contain the dies via a diffusion process. Within the back-end, the wafers are further processed by testing and assembling the dies into final products via respectively the sawing, assembly and final testing processes. The front-end and back-end processes are both part of IMO. Finally we have the shipping part which is the responsibility of the global sales organization (GSO). The order acceptance and production order release is performed by the order fulfillment centers (OFCs).

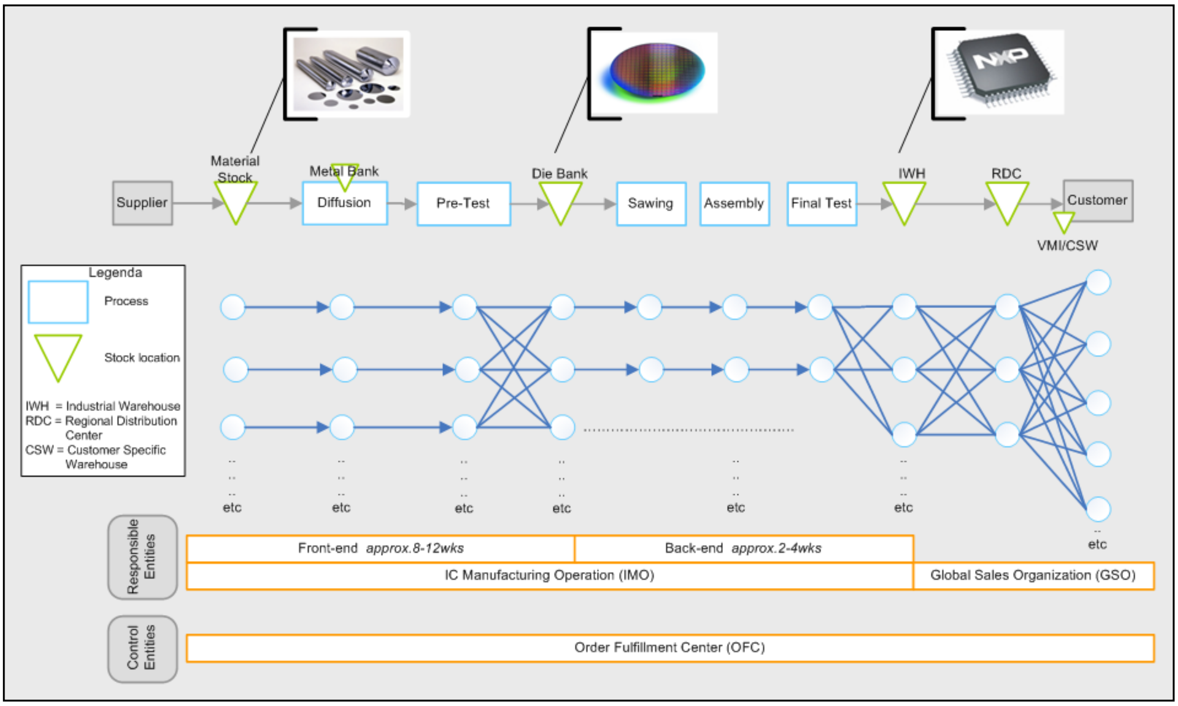


Figure 2.3: NXP's supply chain and control entities

The different production steps can be described as follows (Lee, 2001; NXP, 2007b):
Diffusion: The material stock consists of raw wafers. These wafers are sliced from crystal silicon ingots (see insertion at Figure 2.3). At the diffusion process new thin layers are bonded or baked onto the wafers. This is done using diffusion furnaces, high-pressure oxidation, and rapid thermal processing. The diffusion process, consisting of 300 to 400 process steps, takes place in semiconductor fabrication facilities and are called foundries or wafer-fabs.

Pre-test: Each finished wafer (see insertion at Figure 2.3) may contain several hundred actual devices or dies. Each die on the wafer is pre-tested before the wafer is placed into the die bank. A probe tester uses needle-like ‘probes’ to contact the bonding pads (the circuit connection points) on each die to check its operation. Dies that fail the test are marked with a colored dye for rejection. After this step, the dies are stored in the Die Bank. This is also the end of the front-end.

Sawing: Here the back-end process starts. Wafers from the die bank are first sawn into individual dies. The marked (non-functional) dies are discarded and the functional dies are passed on to assembly.

Assembly: Once separated into individual dies, the functional dies are attached to a lead frame and aluminium or gold leads are attached via thermal compression or ultrasonic welding. Sealing the dies into a ceramic or plastic enclosure completes the assembly (see insertion in Figure 2.3).

Final testing: After assembly, the dies are tested once more for electric properties. After the final test, the final products are packaged in boxes and temporarily stored in the industrial warehouse (IWH), located at the assembly and test plant.

Distribution and Shipping: To get the products from the IWH to the customer’s gate, two different shipping concepts are used:

- *Direct Shipment (DS)*; this is the fastest way of shipment and the customer is directly delivered from the Industrial Warehouse (IWH). This shipment can be seen as the NXP default shipment stream and the objective is to go to 100% direct shipment.
- *Transshipment (TS)*; means that the finished goods (FGs) are first stored in the Regional Distribution Centre (RDC) before they are delivered to the customer’s dock or to a Customer Specific Warehouses (CSW). CSWs are located in or close to customer’s plants (i.e. Vendor Managed Inventory (VMI)). NXP has a RDC in Memphis (US00), Hong-Kong (HK00) and Roermond (NL00). Because of the objective of using 100% direct shipment, this stream is only used in exceptions (in order to reduce lead times) or because of legislation, packing and labeling issues.

In general, parts of the industrial process are spread over more than one geographical location. The front-end operations are performed in the waferfabs (Industrial Centers), namely Böblingen and Hamburg in Germany, Caen and Crolles II in France, Hazel Grove in the UK, Fishkill in the USA, Singapore (SSMC) in Singapore, Jilin in China and Nijmegen in the Netherlands. The back-end operations are performed in the assembly plants. These are concentrated in Asia, namely Bangkok in

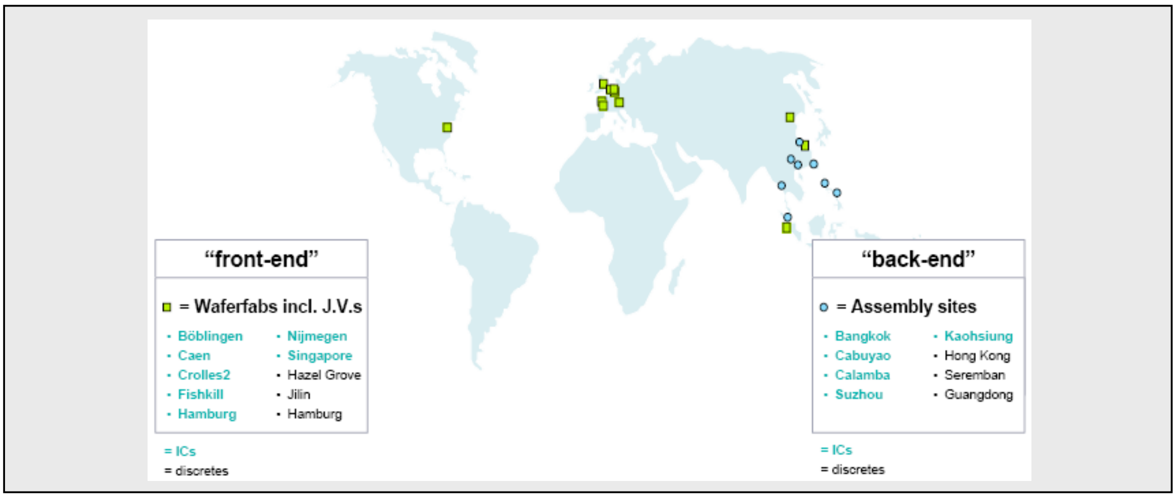


Figure 2.4: NXP’s globally divided front-end and back-end locations

Thailand, Calamba and Cabuyou in the Philippines, Kaohsiung in Taiwan, Seremban in Malysia, Hong Kong in Hong Kong, Guangdong and Suzhou in China (Figure 2.4). The endpoint of the industrial process, where a finished product originates, is typically in one location in the world. Besides that, the customers are widely spread. The Global Sales Organization (GSO) (part of the marketing and sales organization) is divided in several regions, namely North America, Asia Pacific (APAC), Greater China and Europe, Middle East and Africa (EMEA).
Due to the number of different products NXP produces and due to the different locations of front-end and back-end plants as stated above, a large number of goods flows are theoretically possible.

2.1.4 Semiconductor market characteristics

The semiconductor dates from 1947 when the point contact transistor was invented by Bell Laboratory researchers (Schaller, 1996). Later on, the US army subsidy the development of the silicon transistors because old designs were easily affected by intense heat and therefore not useable for military purposes. Since the 1970’s the semiconductor industry developed remarkable and was mainly towed by demand for the desk calculator (Okada, 1995). Today, ICs are found in almost every electronic product, ranching from automobiles to mobile phones. In general, the semiconductor industry can be characterized by the following characteristics:

Rapidly changing technologies:
In 1965, Moore observed an exponential growth in the number of transistors per IC and predicted that this trend would continue. With a doubling period of approximately 18 months, “Moore’s Law” holds true until today (Schaller, 1996). As products becoming increasingly complex, more products and services emerge leading to a reduction of the lifecycle length.

Cyclic market / Market volatility:
Semiconductor companies operate in markets where demand is cyclic. The industry is faced with periods of rapid market growth followed by periods of declining markets. Besides that, as relatively

upstream companies in the supply chain, high variability in demand volume needs to be taken into account. Forecasting is very difficult and customers do not always commit to their demand. However, in case of a stock-out there is a great probability that sales will be lost (Lee *et al.,* 1997).

Asset-intensive:
Capital utilization is an aspect of great importance in this industry due to the fact that huge capital investments are required to build new plants. For example, an investment of about €2 billion is required to build a new diffusion plant. Therefore, investments in factories are typically related to long-term planning. Also, because of these high investments, the primary management goal in the wafer fabs is to maximize throughput (Ovacik and Weng, 1995).

Long manufacturing lead-times:
Within the semiconductor industry, the time commonly needed for production and distribution of end products is generally between 10 and 16 weeks. This time is much longer than the lead-time customers expect when putting in an order. This forces the industry to strategically manage inventory at various stages in the pipeline. To do so, customer order decoupling points (CODP) are introduced in which the product flow changes from 'push' (forecast driven) to 'pull' (order driven) (Mason-Jones & Towill, 1999).

2.2 Project background

The increasing pressure on companies to reduce their logistics costs, to shorten their throughput times and to improve their delivery reliability, together with the globalization of markets and the fast development of information and communication technology as outlined in the previous section, have caused a lot of attention for supply chain management. Supply chain management (SCM) is the task of integrating organizational units along a supply chain and coordinating materials, information and financial flows in order to fulfill (ultimate) customer demands with the aim of improving competitiveness of the supply chain as a whole (Stadtler, 2005). Also NXP faces great challenges in managing the supply chain and in order to deal with them and to be more competitive, at the end of 2004 Business Renewal I was started. At the end of 2006 Business Renewal II has been launched and is part of the 2007 one page strategy (Appendix B). This thesis can be related to the second and the third Business Renewal II objective which are respectively lower the breakeven point and achieve operational excellence.

To decrease the breakeven point of operations, an improvement area is to reduce the sales general & administration (SG&A) costs via improved inventory management. According to a benchmark study performed by the semiconductor logistics forum (Appendix C), NXP is ranked seventh with respect to the total number of inventory turns compared to direct competitors. This benchmark can be seen as an indication that improved inventory management can probably free up cash within NXP and hence decrease the breakeven point. To do so, an inventory management project team is set up to: reduce the value captured by the net inventory levels, to reduce the scrap costs and to increase the sales via America II (a wholesaler for excess inventory). Although literature benchmarks show that the money tied up in inventory can be a significant part of total supply chain management cost, it is generally known that inventories at some locations in the supply chain are unavoidable in order to be able to deliver the right products in the right amounts at the right time to the customer (Tersine, 1994). Hence, reducing inventories in an uncontrolled way will have a direct impact on customer service (Neale *et al.*, 2004). Because improving customer service is a main element in the third Business Renewal II objective, namely operational excellence, both Business Renewal II objectives cannot be treated separately.

This thesis is performed to support the inventory management project team within the Global Supply Chain Management Competence Center by giving them insights in the dynamics between inventory levels and the perceived service levels. With these insights, reducing inventories in an uncontrolled way will be avoided and customer service will be increased.

2.3 Conclusion

NXP operates in a highly dynamic and globalized semiconductor market. The NXP supply chain control is like it peers in semiconductor business quite complex. To manage the supply chain and to deal with the market characteristics, six so called Business Renewal II objectives were launched as part of the one page strategy. On one hand the BR II objectives target for a lower break-even point and on the other hand it aims for operational excellence. For supply chain management this translates in lower stock targets on one hand and better supply chain performance on the other hand. Because of the existing link between these two objectives, this research will support the inventory management project team within the Global Supply Chain Management Competence Center by providing insights in the dynamics between inventory levels and the perceived service levels. With these insights, reducing inventories in an uncontrolled way will be avoided and customer service will be increased.

Chapter 3 Problem formulation

In this chapter the problem will be formulated and the research approach will be outlined. In section 3.1, the problem will be identified by comparing the current with the desired situation as stated in the problem background (section 2.2). Differences between both situations will lead to objectives in order to reduce the gap between both situations. Based on these objectives the point of departure will be defined in section 3.2 and the research goal in section 3.3. The central question with corresponding research questions and the research approach will be described in respectively section 3.4 and 3.5. The conclusions provided in section 3.6 will close this chapter.

3.1 Problem identification

This chapter will give a deeper insight in the current situation (section 3.1.1). This current situation will be compared in section 3.1.2 with the desired situation as already described in the problem background (section 2.2). Based on this comparison we are able to define objectives that will reduce the gap between both situations (Hicks, 1999). An overview of the problem owners will be given in sub-section 3.1.3.

3.1.1 Current situation

During the last few years, several tools were developed which are related to inventory management. These are the Zero Based Inventory Budgeting Tool (ZBIB) and the Supply Chain Configuration (SCC) tool:

1. The ZBIB tool is used to calculate inventory budgets. This tool supports discussion making on inventory target setting. Setting a BL's inventory target is based on calculating the average amount of money (budget) tied up in a stock location or in a production process for the product representatives within a BL. This is done per BL after which consolidation occurs to get the targets for respectively the business unit (BU) and NXP as a whole. The main concern of this budgeting tool is that it does not judge the competitiveness of the inventory coverage and thus no link to the perceived service is made. Because supply chains differ in the network structure, product structure, transportation times and degree of uncertainty they face, one week of inventory supply may be too high for a supply chain X, while three weeks supply may be just right for supply chain Y. Besides that, the safety stock coverage parameters are based on experience.
2. The SCC tool is used to asses the CODP[2] location by providing a relation between the customer order behavior and the perceived service level (on time delivery). To illustrate this tool, suppose that the service level is below target and that the most part of the orders have a requested delivery date within two weeks given the fact that the time needed to flow from CODP to customer dock is four weeks. In this case it could be wise to relocate the CODP to a more downstream (toward customer) location in order to increase service. Although this tool makes the link between service level and order behavior/CODP, it is a weak link (i.e. is a bad service level really caused by a too far upstream positioned CODP or are there other causes like quality or

[2] *See section 4.5 for more details*

capacity problems) and thus can only be used as an indication. Moreover, no insight is given in the costs involved when shifting the CODP to a more downstream location in order to perceive a higher service level.

Within NXP, the coordination of materials through the supply chain is performed by a planning engine (i2) interacting with an ERP system (SAP). These systems do not give support in the decision how much safety stock to position within the supply chain. Safety stock can be defined as inventory that is held to hedge against uncertainties in demand and supply and is held at and before (upstream) the CODP (Van der Heijden & Diks, 1999). Because of the unpredictable environment NXP is in, safety stocks provide protection against running out of stock and hence have a direct impact on the service level NXP is able to provide to their customers. These safety stocks are currently set based on the experiences from the planners in the order fulfillment centers (OFCs) (e.g. 2 weeks of future demand to cover is inserted in the planning engine) without having any insight whether these settings are correct and what the impact of these settings will be on the customer service levels.

3.1.2 Difference between the desired and current situation

At a strategic level, the overall budgets are set, key customers are defined and service level targets are set. To decide how to operationally deal with these strategic targets, decisions are made at the tactical level. This process is depicted in Figure 3.1. The ZBIB and the SCC tool are tools that support decision making at this tactical layer by providing insight in the inventory budget and the correct CODP location but are both not able to link the perceived service levels with the available inventory levels, and more specific the safety stock settings. It is exactly this link which is needed before being able to reduce inventory levels without harming the service level targets as stated in section 2.2. This missing link can also be felt at an operational level, because planners have no insight in the correctness of current safety stock settings and they do have no insight in the effects of changing these settings with respect to the perceived service (of which is strategically determined).
When determining safety stock settings in order to reach a certain service level, several authors

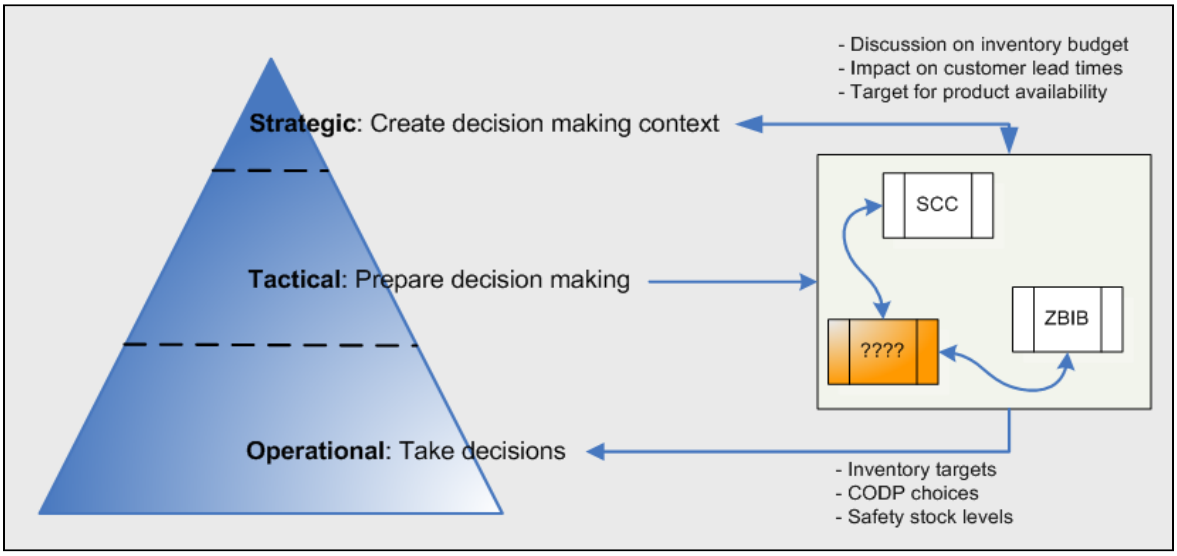


Figure 3.1: NXP's inventory management tools

proved that optimizing a single stock point instead of looking at the whole supply chain network will lead to non-optimal situations (Van der Heijden & Diks, 1999; Graves & Willems, 2000; Lee, 2003; and many more). Hence the network approaches can lead to new insights and improvements over the single location approaches already applied before within NXP.

Based on the identified differences between the desired and current situations, the following objectives can be defined to overcome these differences:

- Support planners in deciding where to place the customer order decoupling point and how much safety stock to keep in all the available stock points in order to support NXP's business in the most effective way.
- Consider integral supply chain networks for safety stock optimization instead of optimizing local stock points.
- Support sensitivity analysis on the relation between the (safety) stock settings (translated into costs) and delivery performance (service level).

3.1.3 Problem owners

The problem owners are the inventory management project team and the planners within the order fulfillment centers. The inventory management project team, on behalf of higher management, is an owner because they have no insight in the relation between inventory levels and the service levels which are respectively part of the second (lower breakeven) and the third (operational excellence) Business Renewal II objective. The planners can be seen as problem owners as well because they are responsible for the safety stock settings but they do not have insight in the correctness.

3.2 Point of departure

Related to the objectives as stated in section 3.1.2 there are two directions to go, namely developing a new model in house or applying an 'off-the-shelf' model that is commercial available. We decided to do the latter because of the fact that such a model generally is able to handle complex networks (i.e. divergent and convergent supply chains). Secondly, such a model is generally speaking user friendlier because it is easier to use and more solid to integrate in the existing systems and data bases. Finally, this approach will save time with respect to formulating the model which can be spend on validating the model because validating is a critical step before using the model in a real business environment.

Today, there are multiple options for commercial multi-echelon inventory optimizer models that meet our objectives. For an overview of these models we refer to the research performed by CapGemini/Ernst & Young (2003). Although the wide variance of models available, we decided to use the Supply Chain Optimizer and Evaluator (SCOpE) model developed by the consultancy firm CQM. Reasons for doing so is that this tool uses the current CODP settings while optimizing the safety stock settings. This will provide deeper insights in the cause and effect relation between safety stock and service levels. Moreover, it will enhance the learning process when applying the model in practice and will provide us possibilities to use this model in combination with SCC and ZBIB. Using an integral model (e.g. i2 inventory optimizer) will optimize the CODP location as well as the safety stock setting. Although the CODP location must be set in a rational way, automatically optimizing this decision ignores the fact that the CODP locations within NXP are often set based at a strategic level (e.g. key-customer or not) instead of looking at the pure order behavior only.

3.3 Research goal

A research goal gives insight in the purpose of performing a research, as well as insights in the stakeholders who take benefit of the end result (Verschuren & Doorewaard, 1995). In general, the research goal will follow from the perceived gap between the current and the desired situation. In section 3.1.2, we indicated three objectives to overcome these differences and we already made a selection for an off-the-shelf model, namely SCOpE. Starting from here, the research goal can be formulated as follows:

Assess the usability of SCOpE within NXP taking into account the customer order behavior and preferences in order to increase the insights of the planners and management with respect to the relation between the perceived service levels and the inventory settings and especially safety stock settings.

3.4 Central question

Based on the research goal, the following central question can be formulated which states what will be examined in this thesis:

Can SCOpE be used for defining the optimal safety stock settings over a network in reference of customer order behavior and preferences and what are the implications of doing so?

3.5 Research questions and approach

Because of the fact that the central question is too broad to tackle in once, the central question is divided into three research questions:

1. *What can be learned from the existing literature related to inventory management and how does it apply to NXP?*
2. *In what way can SCOpE be used for defining the optimal CODP and safety stock settings and how can we increase the accuracy of the results given?*
3. *What are the benefits, limitations and application areas when applying SCOpE within NXP?*

By formulating the answers on these research questions we have gained enough insights to provide an answer on the central question and to generate the conclusions and recommendations of the research performed. To answer the research questions, several sub-questions are formulated which can be linked to the research approach followed. Under each sub-question an elaboration of the activities that will be performed is given.

1. What can be learned from the existing literature related to inventory management and how does it apply to NXP?
   1.1. *What are the reasons for holding safety stocks, and how can this concept be related to the total inventory levels with relevant costs, the CODP locations and the service levels?*

   Literature research need to be done in order to get insight in the rational for holding inventory and especially safety stock. Furthermore, insight must be gained in CODP settings and the effects of changing this location in relation to customer service levels and to the cost involved. All these inventory management concepts must be linked to NXP to get a better understanding of the practical situation. Interviews will be held with supply chain managers, data engineers and planners. Because of the specificity and complexity of the information that is gathered, it is chosen to gather the data with structured oral interviews. The information gained within this sub-question can be seen as relevant background information, necessary to be able to apply SCOpE in practice.

   1.2. *What are the benefits of using an end-to-end approach for inventory optimization instead of a single location approach?*

   Again, literature research needs to be done to get insight in the different approaches available for optimizing safety stock settings. An overview will be given with respect to the benefits of using end-to-end approaches and why this will suit for the NXP environment. This will confirm the choice of using an end-to-end approach based model like SCOpE and will provide deeper insights in safety stock placement possibilities over a network.

The result of this first research question provides general background information with respect to inventory management concepts and provides insights in the potential benefits of an end-to-end approach like SCOpE. After that we are able to start the second research question.

2. In what way can SCOpE be used for defining the optimal CODP and safety stock settings and how can we increase the accuracy of the results given?
   2.1. *What are the relevant input and output parameters of the SCOpE model and how can we retrieve them within NXP?*

   Because we will see SCOpE as a black box, we will not elaborate on the mathematical calculations used within SCOpE. Although, the input and output parameters must to be known as well as the way to retrieve the necessary data/information. To do so, the SCOpE model will be analyzed with respect to its input and output parameters. Data will be retrieved from the different systems within NXP and eventually transformed in order to get the correct input. At the end of this sub-question we will make an initial choice about how to link the SCOpE input parameters to the available information within NXP. Whether this choice is correct and how it can be improved will be dealt with in the next two sub-research questions.

2.2. *How to validate SCOpE in a practical environment and what input parameters can be identified as critical and hence should be improved to increase validity?*

To test whether SCOpE provides the answers as expected, we have to test the model via a validation phase. In literature a distinction is made between verification and validation (Law & Kelton, 2000). *Verification* is determining that a simulation computer program performs as intended, i.e., debugging the computer program. *Validation* is concerned with determining whether a conceptual model is an accurate representation of the system under study. Validation, cannot be assumed to result in a perfect model, since the perfect model would be the real system itself (by definition, any model is a simplification of reality, but not simpler). Literature should be used to perform a good case study selection in order to validate the model.

During validation, mismatches between the modeled and practical situation will be identified during a specific period in the past. It is important focus on those mismatches that are caused by incorrect safety stock setting because this will give us insight in the validity of SCOpE. To find out whether it makes sense to focus on certain root causes, a sensitivity analysis can be performed to see the effect on the safety stock settings or service levels while taking into account the wrong input parameters. This way of working will identify the critical input parameters which have a relative big impact on the validity of the application of SCOpE in practice. Hence it make sense to focus on these parameters in order to increase the validity of the SCOpE model. How to do this will be answered in the next sub-research question.

Because we will retrieve information about the verification and user friendliness while validating SCOpE, we will provide the main observations of these assessments as well.

2.3. How can we improve capturing the critical parameters?

The previous sub-research question provides critical input parameters which have a relative big impact on the validity of the application of SCOpE in practice. Incorporating these input parameters in the most correct way will increase the validity of SCOpE. To do so, relevant literature will be used and discussions/interviews will be set up with planners to come to the right decisions. These discussions will partly be held via face-to-face interviews. This will not only increase the quality of the discussion but will also increase the commitment of the planners which can help to implement SCOpE in a later stage. Important to realize is that the performed improvement steps should be validated/tested again in order to be sure that the steps made are making sense. This will result in a interactive character between research question 2.2 and 2.3.

The result of the second research question is a thorough understanding of the relation between the safety stock settings and the perceived service levels. Moreover, the critical parameters which have a high impact on the validation result are identified and the way of capturing these parameters will be improved to increase the validity. The next research question will deal with optimizing current networks in order to find the real benefits of SCOpE.

3. What are the benefits, limitations and application areas when applying SCOpE within NXP?
   3.1. *What are the benefits and limitations when applying SCOpE to the chosen case studies?*
   After we selected case studies (RQ 2.2) and we have dealt with the critical input parameters (RQ 2.3), we are able to apply the model for these case studies. When doing this we will gain insight in the benefits and limitations of the SCOpE model when optimizing supply chain. Again planner involvement is needed to find out whether they agree with the proposed safety stock settings.

   3.2. *What are the application areas for SCOpE within NXP?*
   Because we initially applied the model to selected case studies only, the question that arise is how to apply the model within NXP. We need to find out where we are able to use the model and what the implications are. Furthermore, we will link the model to the other available tools as described in the problem identification to define how to use SCOpE in practice and also when to use the model.

The result of the third research question will provide the answers related to the implications of using SCOpE in practice with respect to benefits, limitations and application areas. Based on these results we are able to answer the central question and to generate the conclusions and recommendations of the research performed.

3.6 Conclusion

During the problem identification phase, we identified a gap between the current and the desired situation and based on that we were able to define three objectives to overcome this gap. First, there is a need to support planners in deciding where to place the customer order decoupling point and how much safety stock to keep in all the available stock points in order to support NXP's business in the most effective way. Second, an integral supply chain network should be considered for safety stock optimization instead of optimizing local stock points. Third, a sensitivity analysis on the relation between the (safety) stock settings (translated into costs) and the delivery performance (service) is needed. Based on these three objectives, in combination with the decision that an off-the-shelf optimizer will be used (SCOpE), the central question can be formulated as follows:

Can SCOpE be used for defining the optimal safety stock settings over the network in reference of customer order behavior and preferences and what are the implications of doing so?

This question is divided into the following three research questions:
1. What can be learned from the existing literature related to inventory management and how does it apply to NXP?
2. In what way can SCOpE be used for defining the optimal CODP and safety stock settings and how can we increase the accuracy of the results given?

3. What are the benefits, limitations and application areas when applying SCOpE within NXP?

By formulating the answers to these research questions, we have gained sufficient insights to provide an answer on the central question and to generate the conclusions and recommendations of the research performed. A schematic overview of this thesis is depicted in Figure 3.2.

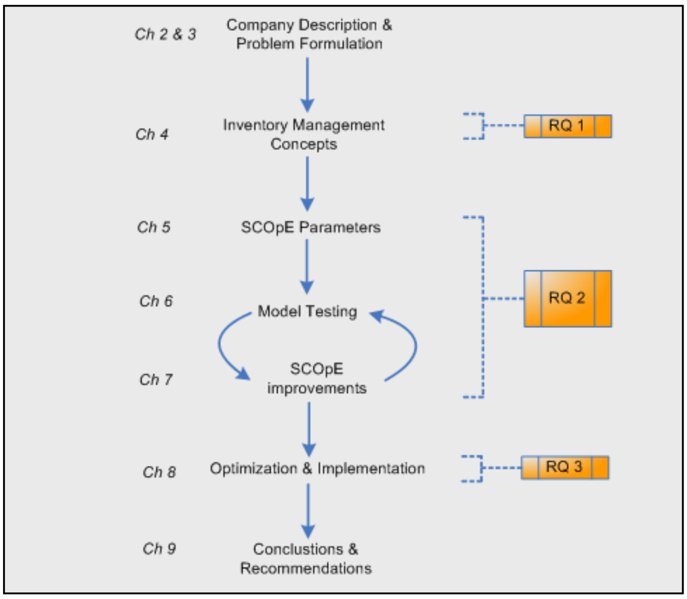


Figure 3.2: Research approach

Chapter 4 Inventory management concepts

Now we have formulated the problem and the research approach, this chapter will answer the first research question by exploring relevant inventory management concepts and linking them directly to the situation within NXP. Furthermore, insights in the benefits of using end-to-end approaches like SCOpE are given. This information is needed to be able to work with SCOpE.
We will start in section 4.1 by classifying inventory in order to make clear that safety stocks are only a single element of the total available inventory within a company. In section 4.2 we will show the importance of inventory by providing the relation between the costs involved and the service perceived. In section 4.3 the CODP and the safety stock concepts will be explained via literature and via the application of these concepts within NXP. In section 4.4 we will describe two approaches for optimizing safety stocks and the benefits of using an end-to-end approach like SCOpE. The chapter will be closed by a conclusion.

4.1 Inventory classification

This whole thesis is focusing on the safety stocks. Because safety stocks are just one part of the total inventory a company owns, we will elaborate on the term inventory by a classification of the different types of inventory available (Tersine, 1994):

- *Working (or cycle) stock*: Inventory acquired and held in advance of requirements so that ordering can be done on a lot size (in order to get benefits of economies of scale) rather than on an as needed basis.
- *Pipeline (or work-in-process) stock*: Inventory put in transit to allow for the time it takes to receive material at the input end, send material through the production process and deliver goods at the output end. This component can only be reduced by reducing the stacked lead times (physical and information lead times).
- *Safety stock*: Inventory held in reserve to protect against the uncertainties of supply and demand. Safety stock can be defined as the average inventory level just before the arrival of a replenishment order (Van der Heijden & Diks, 1999).
- *Anticipation stock*: Inventory built up to cope with peak seasonal demand (pre-builds), erratic requirements (promotion programs, strikes, vacation shutdowns) or deficiencies in production capacity.
- *Decoupling stock*: Inventory accumulated between dependent activities or stages to reduce the requirement for completely synchronized operations.
- *Psychic stock*: Inventory carried to stimulate demand and act as a silent salesperson (e.g. spot deals[3]).

Tersine (1994) is focusing with this classification on planned inventory, however, inventory is not always a result of good planning. For instance, inventory in a stock point can increase when the lead

[3] A spot deal is an order that will be placed at a semiconductor supplier that meets the specification and is able to deliver on time. Building up inventory will reduce the lead time and increases the probability that the order will be confirmed at NXP instead of at one of is competitors.

time of an incoming flow is shorter than expected, the yield of an incoming flow is higher than expected or when an order is cancelled or returned. Despite this classification, most manufacturing operations do not have such a tight classification. Rather, they have large work-in-process inventories which are serving multiple purposes: Protect against various uncertainties and disruptions, permit production smoothing and provide some decoupling across multiple production stages (Graves, 1987).

Within NXP a similar classification as given by Tersine (1994) occurs. In Figure 4.1 the class stock reporting (CSR) at the start of august (BL MMS-PM; Back-end stock) is depicted. Related to the history (< wk31), the total inventory quantity is the sum of the history stock and the history work in process (WIP) inventory. The WIP inventory is defined as all the stock that is not located at a stock location. Related to the future (> wk30), the projected total inventory quantity is based on a combination of the future order book and the forecasted sales. The WIP in the future is a combined figure of actual and planned start ups. The safety stocks are a part of the projected inventory meaning that the difference between these two figures will function as cycle (e.g. batching), anticipation, decoupling and physic stock. The projected inventory in the future will remain stable and is the result of stock that is non- or slow moving. This can be the result of a wrong forecast in a previous period (e.g. more start ups than needed) or a wrong allocation of stocks over the network (e.g. risk of obsolescence when having large stock quantities down stream the supply chain).

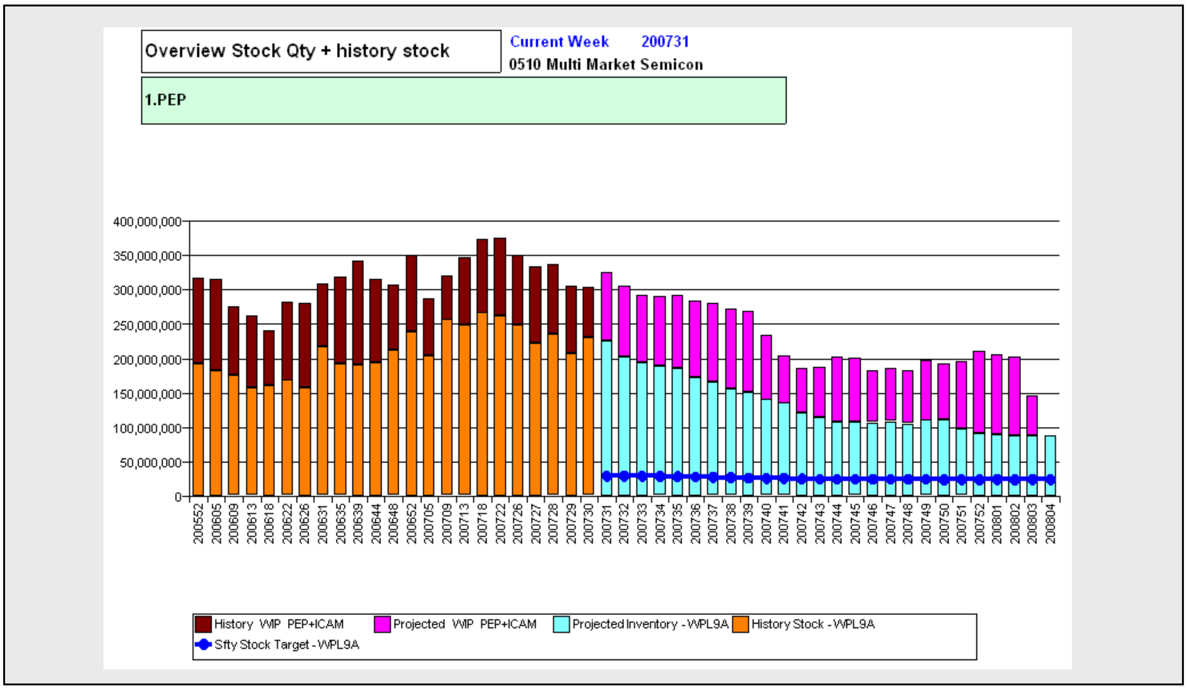


Figure 4.1: Snap-shot Class Stock Reporting (Back-end MMS-PM, end of August'07)

4.2 The importance of inventory

As already indicated in section 2.2, better management of inventories throughout the supply chain represents a huge opportunity for businesses. Inventory is critical because it directly impacts both costs and service. Since demand is almost always uncertain and it takes time to produce and transport products, inventories at some locations in the supply chain are unavoidable in order to be able to deliver the right products in the right amounts at the right time to the customer (Tersine, 1994). But, increasing supply chain inventory typically increases customer service and consequently revenue, but it comes at a higher cost (Neale *et al.*, 2004). This relationship can be described by a graph often referred to as the "efficient frontier" (Figure 4.2). For each possible end customer service level, the efficient frontier plots the minimum amount of supply chain inventory required to achieve that service level. The aim of supply chain inventory management is both to get a supply chain onto the efficient frontier by having the correct inventory level (1→2, Figure 4.2) and to shift the efficient frontier outward through better inventory strategies and supply chain designs (2→3, Figure 4.2). The goal of this chapter is to highlight the importance of inventory by exploring its impact on costs (section 4.2.1) and service in more detail (section 4.2.2). We will directly link the literature to the NXP situation because this will give us the needed information for applying a model for determining safety stock settings in a later phase of this thesis.

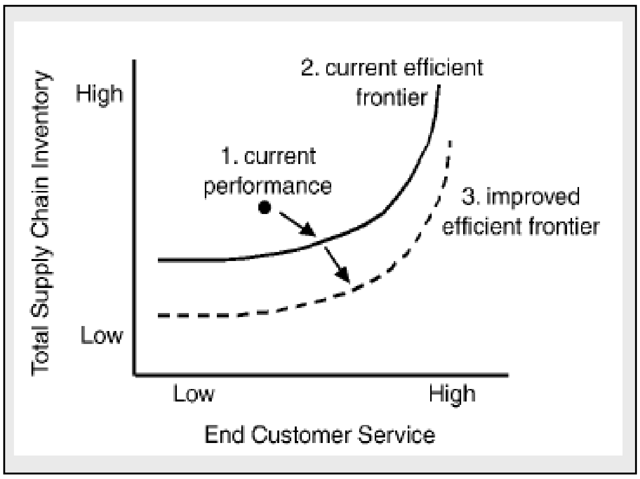


Figure 4.2: The efficient frontier and inventory improvement goals (subtracted from Neale *et al.*, 2004)

4.2.1 Inventory driven costs

According to Callioni *et al.* (2005), inventory driven costs include the following: Traditional inventory costs, component devaluation costs, price protection costs, product return costs, obsolescence costs and opportunity costs. The *traditional inventory costs* cover the capital cost of money tied up in inventory and the physical costs of having inventory (warehouse space costs, storage taxes, insurance, rework, breakage, spoilage). *Component devaluation costs* occurs when a product held in inventory loses value over time. *Price protection costs* are related to policies which avoid that the companies customers are selling items with a loss when the price

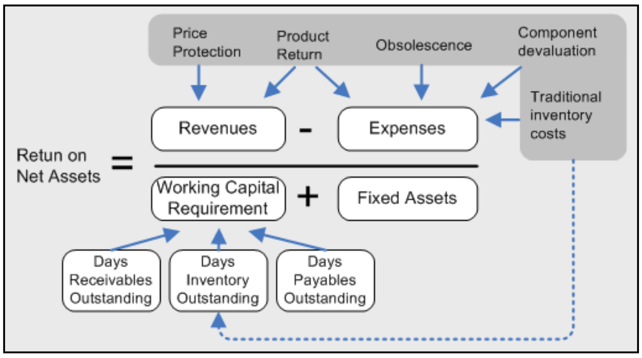


Figure 4.3: Effects of inventory costs on RONA (subtracted from Callioni et al.,2005).

suddenly decreases after a shipment is done. These cost do only occur for suppliers that are not directly selling their products to end-customers but via a distributor or retailer and dictate the market price the distributors or retailers have to use. *Product return costs* are simply 100% price protection costs because customers can simply return unsold products to the manufacturer for a full refund. *Obsolescence costs* are incurred when a product reaches the end of its life and all remaining inventory must be scrapped or sold at extreme discounts. All these costs are not placed as direct expenses at the income statement but do appear in a variety of places on the income statement or as a performance measurement. On such a performance measurement is the return on net assets. The return on net assets is a performance measurement and is the ratio of income to total assets (Brealey & Myers, 2003). As can be seen in Figure 4.3, reducing the traditional inventory costs (e.g. reducing the inventories) does not only lead to costs reductions, but also leads to a reduction of the days inventory outstanding. Both reductions will increase the return on net assets performance because the expenses and the working capital requirements will decrease both. Often, the total cost tied up in inventory (traditional inventory costs) are expressed as an *opportunity cost*. The opportunity costs, captures the return that could have been achieved if the money invested in inventory had been invested elsewhere. A general used percentage for this is the weighted average cost of capital (WACC) which is a company wide used percentage applied internally to all investment decisions (Brealey & Myers, 2003).

Within NXP, the only deviation is made between obsolescence and traditional inventory costs. These two components are responsible for 44% of NXP's supply chain management costs meaning that the obsolescence costs (scrap) were € 50 million in 2006 and the average money tied up in the net inventory level was approximately € 690 million in 2006 (€ 110 million is labeled as safety stock), implying an opportunity cost of € 86 million (=net inventory level * WACC = € 690 million * 12.5%). In order to measure the competitiveness of the inventories, NXP uses an inventory percentage[4] as a financial key performance indicator (KPI) within their business balanced scorecard (BBSC). Currently, the targets for this KPI are set at management level per BL.

4.2.2 Service measurements

Service is generally described as the ability to satisfy a customer demand within a certain time. The following four measurements are commonly used (Silver *et al.*, 1998):

1. The *no stockout probability* or *cycle service level* (P_1-measure) is the fraction of cycles in which a stockout does not occur. A replenishment cycle is defined as the time interval of two subsequent replenishment orders that have been issued by the stock point. A stockout is defined as an occasion when the on-hand stock drops to zero. A drawback is that this measure does not provide any information on the amount of demand that could not be served during a replenishment cycle.
2. The *fill rate* (the P_2-measure) is the long run fraction of demand that is delivered immediately from stock on hand (i.e. without backorders or lost sales). It gives a better idea of the on-time delivery performance and is therefore often used in practice. On the other hand, it does not provide information on the fraction of orders (that may consist of multiple order lines) that have been

[4] *Inventory percentage is measured as the stock value at the end of the month as percentage of annualized sales of the last three months. See Appendix C for the percentages per BU/BL over 2006.*

delivered completely and timely. A core assumption when using this measurement is that partial deliveries are possible (rest is a backorder) and will not result in a lost sale.

3. The *ready rate* (P_3-measure) is the long run fraction of the time that inventory is available (i.e., non zero). It provides information on the inventory status, but not immediately on customer service because when there is no demand until the next replenishment order arrives, a zero inventory level is no problem.
4. The *average number of backorders* is another measure that is used for backorder cost calculation, if shortage costs can be assigned (per item and per time unit that the item is backordered). In some applications backorder costs are a relevant variable (e.g. spare part systems). A drawback is that this measurement does not distinguish between many backorders that are filled after a short time period and one backorder that has to wait extremely long before it is filled: the expected backorder level can be the same.

Inventories throughout the supply chain have a direct impact on the availability of the products and thus the perceived service. Not reaching a predefined service level will often lead to lost sales, and in some cases financial penalties (Silver *et al.*, 1998). Setting the correct customer service target is a critical dimension of supply chain competition and a key driver of inventory level (Neale *et al.*, 2004). These authors state that service to the end customer is the key issue because customers are only interested in this performance and not in the performance within internal stages in a supply chain. Furthermore, service targets need not be the same for all products in a supply chain. Some customers will receive higher service levels often based on the fact whether this is a key customer or not. Finally, a company must know how customers measure service to avoid miscommunication.

Within NXP, three service measurements are used. These are all different than the four common used measurements found in literature. The service measurements within NXP are respectively the LAP, CLIP and RLIP which can be defined as follows:

1. *The line acceptance performance* (LAP) is the number of customer order lines that are confirmed at the customer requested date, expressed as a percentage of the total number of customer order lines for the period under analysis. This measurement gives insight in whether the customer expectations are met.
2. *The confirmed line item performance* (CLIP) is the number of customer order lines completely delivered before or on the day for which they were first confirmed, expressed as a percentage of the total number of customer order lines for the period under analysis. This measurement can be seen as an internal service measurement and gives insight whether NXP kept their promises of the confirmed delivery date.
3. *The requested line item performance* (RLIP) is the common used service measurement of NXP to the outside world and is the product of the LAP and the CLIP. It calculates the percentage of order lines that are delivered on time given the requested delivery date (Figure 4.4). NXP decided that all orders within the window of 2 days before or 1 day after the customer order request date are within the 'OK area' and thus on time. Not allowing more than 2 days delivery before the request date is to avoid stocking costs at the customer's site. The reason of allowing a delivery 1 day too late is commonly accepted within the semiconductor industry.

$$RLIP\% = \frac{\sum(\text{the.orders.delivered.in.OK.area})}{\sum(\text{orders.requested})} * 100\%$$

Figure 4.4: Common used service measurement within NXP

NXP uses a similar RLIP target per BL for all products they deliver with the exception of customer specific warehouses (CSW or VMI) that perceive a 100% RLIP. A distinction of delivery performance is made based the CODP location and thus the order lead time that can be given to a customer. We will come back to this issue in the next section. The CLIP and RLIP measurements are both lacking measurements, meaning that they only can be measured afterwards. Besides that, the RLIP measurement assumes that customers are ordering according to their CODP location. If that is not the case, you generally have a LAP miss (the order is confirmed at a later date than the requested date), a CLIP hit (the order is delivered at the confirmed date of NXP) but a RLIP miss (the order cannot be delivered at the requested date because of the lead time needed). This phenomena does occur within NXP and we have to realize this when using RLIP as performance measurement during this thesis. Furthermore, the current measurement can lead to 'CLIP or RLIP hunting', meaning that a high CLIP or RLIP can be achieved by neglecting big orders. Because of these two statements we can argue whether RLIP is a good service measurement. We will not elaborate on this issue because it is another research topic. Furthermore, strategic behavior will always occur and the challenge should be to make the planners aware of the impact of their strategic behavior on the overall company performance.

4.3 CODP locations and safety stocks

The customer order decoupling point (CODP) is a standard term given to the position in the material pipeline where the product flow changes from 'push' (forecast driven) to 'pull' (order driven) and thus is the point in the product axis to which the customer's order penetrates (Mason-Jones & Towill, 1999). Upstream the CODP (toward the raw materials), the items that are kept in stock are those items for which demand must be forecasted due to the fact that future demand between the moment of release of items and the moment those items are received is (partially) unknown; the lead time of supplying the item is longer than the lead time requested by the customer. Downstream the CODP (toward the customer), items are not kept in stock since future demand for these items between release moments and receipt moments is known and hence the only inventories in this part of the supply chain are WIP and cycle (e.g. batching) inventories; the lead time of supplying the item from the CODP to the customer is shorter than the lead time requested by the customer (De Kok & Fransoo, 2003). Because we will focus on safety stocks, we will only deal with the part of the network until the CODP location.

Within NXP, the CODP locations are set per 12NC[5] seller-ship-to combination. A seller (e.g. Philips) is a NXP used acronym for a group (one or more) of customers (often the specific seller-ship-to

[5] *Every product that flows through the supply chain has its own (identical) 12NC-code. Because a die results in multiple end products within the back-end process, the 12NC-code changes after it left the die bank (e.g. Die 331373484301 results in end-product 934003470215; 934056996215; etc.).*

combinations like Philips Lighting; Jabil circuit HK LTD. etc.). Because a specific end-product can be delivered to multiple sellers and within that to multiple ship-to locations, each end-product can have multiple CODP settings. Although this complexity, the CODP location is generally set to the most possible upstream stock location because of the fact that the inventory costs (i.e. value adding costs) and risks (i.e. obsolescence) increase when going more downstream. Because not all customers are accepting such a long order lead time, NXP makes a strategic trade-off between the importance of this customer to NXP and the well willingness of NXP to take risk in order to meet the customers expectations with respect to the accepted order lead time. When both criteria are answered by a 'yes', the CODP is set to a more downstream location.
In order to provide 100% service or reduced lead times to certain (key)-customers, customer programs (CP) are introduced with a CODP located at respectively a CSW or at an IWH/RDC. Besides the reduced order lead times, CPs have the advantage that their orders are prioritized in case of allocation. For more details of the order entry, release and shortages we refer to Appendix D.

Safety stocks are held to hedge against uncertainties in demand and supply and are held at and before (upstream) the customer order decoupling point (Van der Heijden & Diks, 1999). According to these authors, the relative size of safety stocks can change because of several reasons:

- Safety stocks increase when the expected lead time increases because the variation in demand has to be covered over a longer period.
- Safety stocks decrease when the review period increases (infrequent replenishments) because the cycle stocks 'take over' a part of the buffer function. This effect can even lead to negative safety stocks (i.e. when the cycle stocks are very high and the service level requirement is not extremely high).
- Safety stocks will increase when service levels increase as well because the probability that you are running out of stock during a replenishment cycle must be decreased.
- Fourth, the safety stocks will increase when the uncertainties in demand or supply increase.

Within NXP two sorts of safety stocks can be distinguished:

1. *Buffer specific safety stock* means setting a safety stock on a hierarchical level within the supply chain (e.g. safety stock located die bank) which can be used by all customers.
2. *Customer specific safety stock* is set for the CP-customers only and will increase the ATP (available to promise capacity) for this specific customer. Customer specific safety stock can therefore only be used by this specific CP-customer and is only set at the CODP location (i.e. CSW or IWH/RDC). At the stock points upstream the CODP, CP-customers are able to use the buffer specific safety stock.

Both kind of safety stocks are a fixed or a dynamic setting. *Fixed safety stock settings*, means that a safety stock quantity is set without any relation to the (future) demand. *Dynamic safety stocks* means that a safety stock is set via the number of weeks to be able to cover future demand. This future demand is calculated based on the forecast figures over a rolling period of n weeks (n=look ahead period). The risk of obsolescence decreases when using dynamic safety stocks, but in order to be pro-active to the market (e.g. in a ramp-up phase when forecast is highly unpredictable) fixed stocks are used. As already indicated in section 3.1.1, the safety stock settings are currently based on the planner's experiences.

4.4 Approaches for optimizing safety stock placement

During the problem identification one of the defined objectives is to use an integral network approach. This section will provide background information of the benefits of using such an approach. The basis is given by the single location approaches (section 4.4.1) which are the building blocks for more sophisticated end-to-end approaches (section 4.4.2). Section 4.4.2 will focus on the benefits instead of mathematical formulations in order to get a better understanding of using end-to-end approaches within NXP.

4.4.1 Single location approaches: Base stock and safety stock

For inventory control of a single stock point, there are several rules used in practice (e.g. (R,s,Q); (s,Q); (R,s,S); (R,S); (s,S), see Silver *et al.* (1998) for a broader explanation). The inventory control rule commonly used in practice and also within NXP, is the Base Stock (or Periodic Review, Order up to level (R,S)) control rule as depicted in Figure 4.5. In a (R,S) system, every R units of time a replenishment order is placed of sufficient magnitude to raise the inventory position to the order-up-to (or base stock) level S. The *inventory position* is represented as the actual inventory at a given point of time in the warehouse plus inventory in transit plus inventory on order with supplier minus the current sales backlog. This *replenishment order* is on average the mean demand during period R (so $\mu_D(R)$). The *review interval (R)*[6] is the time between two successive planning periods. When selecting S at time t_0 we must recognize that, once we have placed order X, no other later orders (in particular Y) can be received until time t_0+R+L. Therefore, the order-up-to level S at time t_0 must be sufficient to cover demand through a period of duration R+L. A stockout will occur at the end of the current cycle (e.g. at time t_0+R+L) if the total demand in an interval of duration R+L exceeds S. In case in which this demand is not deterministic but stochastic, the uncertainties in demand can be covered via safety stock (SS) in order to avoid stock outs. See Appendix E for the mathematical expression of this inventory control rule.

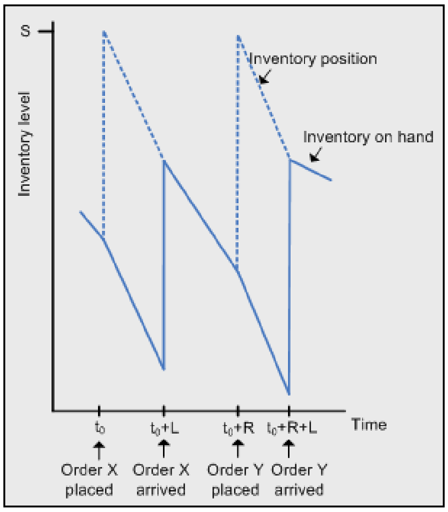


Figure 4.5: Visualization of the Base Stock (or R,S) policy

4.4.2 End-to-end approaches

Single location approaches as stated in the previous subsection can be a big improvement over the simple rules-of-thumb still used in many companies (Neale *et al.,* 2004). But, optimizing over a network (multi-echelon) will even lead to more savings (Graves & Willems, 2000; Lee, 2003; Van der

[6] The determination of R is equivalent to the determination of an economic order quantity expressed as a time supply (for more details we refer Silver et al., 1998). In practice the R is commonly dictated by external factors (e.g. frequency of truck deliveries) and is obviously restricted to a reasonably small number of feasible discrete events.

Heijden & Diks, 1999; and many more). An example of a multi/three-echelon model is depicted in Figure 4.6 which is in line with the multi-echelon situation as occur within NXP (section 2.1.3).

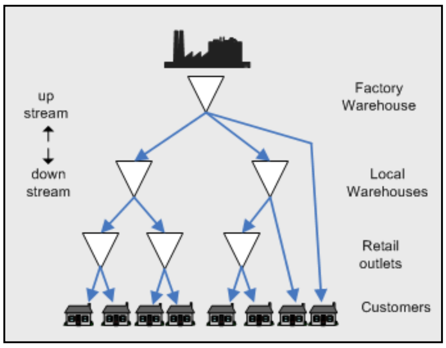


Figure 4.6: Multi-echelon representation

There are several benefits when looking at the whole network while determining the inventory levels in each stock point in order to meet a pre-defined service level. First; a *reduction of inefficiencies caused by the bullwhip effect*. The bullwhip effect is the effect that demand variability increases as orders are passed through the supply chain from customer to supplier. This increase of variability requires additional inventory upstream and can be avoided by collaboration between supply chain partners and thus, using the same average demand and variation for all participants within this network (Lee *et al.*, 1997). Second; *risk pooling* will lead to lower inventory levels via the fact that demand is better predictable at an aggregated level (i.e. more upstream). Third; a *reduction of imbalance* via the fact that upstream inventory can be used to fulfill orders from multiple downstream locations. When the inventory is already allocated to more downstream locations it can happen that one downstream location has plenty of stock while another downstream location does not have stock at all. This problem is caused by a wrong allocation in the past and when there is no central stock it will take a long (lead) time before the imbalanced situation can be corrected. Fourth; a *reduction of costs* via the fact that inventory in a more upstream location is in general cheaper than inventory in a more downstream location. Fifth, it is not necessary anymore to provide high service levels between all echelons because only the service to the end customer is relevant. In order to capture these benefits, an integrally controlled system requires a central authority deciding upon inventory control and stock levels because all allocation decisions have to be taken centrally as well. Within NXP, a centrally controlled system is available and already used, namely the i2 planning engine as well as a SAP system to manage the information over the supply chain.

Having outlined these benefits, the main challenge is to decide how the inventories should be allocated over the network. In literature, two approaches to optimize safety stock placement in a multi-echelon supply chain appear; guaranteed service models and stochastic service models. Only a short description is given of these two streams to get some basic insights in the differences (Graves & Willems, 2003; Lesnaia, 2004).

- Within the *guaranteed service models*, delivery or service time between stages is quoted (deterministic) and can always be satisfied and therefore the service provided to customers is guaranteed. Consequently, each stage has to hold sufficient inventory to satisfy the service time commitment. Therefore, the goal is to determine the best choice of internal service times within the SC that minimize the total cost of holding inventory in supply chains. Hence, this stream of models are not directly determining the needed inventory levels.
- Within the *stochastic service models*, the delivery or service time between stages can vary based on the material availability at the supplier stage. This is caused by the phenomena that a stage

upstream can not always deliver demand requests directly from stock and thus each stage will occasionally experience a delay in obtaining its supplies from its upstream suppliers (i.e. the effective lead time is longer than the nominal lead time because of the out of stock situations). Due to this stochastic delay, the replenishment time for the stage is stochastic as well. The goal is to optimize the inventory level per stage given the requirement that each stage has enough inventory to meet a service level target requirement given to the end customers.

SCOpE can be positioned under the stochastic service models and will be discussed in the next chapter.

4.5 Conclusion

Research question 1 is about what can be learned from the existing literature related to inventory management and how it applies to NXP. We are able to make the following conclusions:

- There are multiple reasons for holding inventory of which safety stocks are only a minor part. Safety stocks are held to hedge against uncertainties in demand and supply.
- Inventories at some locations in the supply chain are unavoidable. Increasing supply chain inventory typically increases customer service and consequently revenues, but also costs. Hence a trade-off between these parameters needs to be made constantly.
- Inventory costs have a direct impact on the return on net assets and can be seen as opportunity costs because money invested in inventory cannot be invested elsewhere.
- NXP uses three service measurements which are different from the common used measurements in literature. Despite the differences, literature suggests that it is important that the customer understanding of service is in line with the NXP used terminology.
- The CODP location is the term given to the position in the material pipeline where the product flow changes from ‘push’ (forecast driven) to ‘pull’ (order driven). Within NXP, the CODP location depends on the strategic intend toward its customer. Whether this is in line with the customer behavior/expectations is hardly assessed.
- By definition, safety stocks can only be placed at and upstream the CODP locations. Within NXP, safety stocks can be set buffer vs. customer specific and besides that fixed or dynamic.
- Literature proved that end-to-end approaches result in several benefits compared to single location approaches. This is the result of a central control function which reduces the bullwhip effect, risk pooling because demand is better predictable at an aggregated level, reduction of imbalance because upstream inventory increases the flexibility, reduction of costs because inventory upstream is in general less expensive, only a high service to end customers is needed and not between the multiple echelons.
- A multi-echelon situation applies to NXP as well and hence it makes sense to use an end-to-end approach like SCOpE for inventory optimization, and more specific safety stocks.

These insights provide us enough background information to be sure we are familiar with the basic inventory management terminology necessary to work with an inventory optimizer like SCOpE.

Chapter 5 SCOpE parameters

As described in chapter 3.2, we have chosen the supply chain optimizer and evaluator (SCOpE) as model to determine the optimal safety stock settings over the network. This model will be considered as a black box with respect to the mathematical calculations. For more details we refer to the papers of De Kok & Visschers (1999); Van der Heijden *et al.* (1997); and De Kok & Fransoo (2003). In order to apply the proposed model to a practical situation, the basic structure and assumptions made should be known. In respectively section 5.1 and 5.2 we will outline the relevant input and output parameters of the SCOpE model. In section 5.3 we will explain how to retrieve the input parameters from the different sources within NXP. In section 5.4 we will discuss some modeling issues and assumptions SCOpE makes. We will close this chapter with a conclusion before testing the model in chapter 6.

5.1 Input parameters SCOpE

The input parameters SCOpE uses can be categorized related to the demand, supply and system logic. These parameters completely describe the value network in terms of demand characteristics, planned lead time structure, value structure and BOM structure. In Appendix F two snap-shot of SCOpE are depicted.

Demand side

- N The number of end-items taking into account.
- $E[D_i]$ Expected demand per period for end-item i. Generally, this demand is represented by the forecast. The expected demand is generally represented by the forecast and is used to determine the order up to levels per stock location. Expected demand at an upstream stock point is determined by aggregating the demand of the directly connected downstream stock points.
- $\sigma[D_i]$ Standard deviation of errors of forecast over a period for end-item i. Demand variations are representing the differences between supply (based on forecast) and demand (based on actual orders). These variations need to be known because you are setting safety stocks because of these mismatches (i.e. forecast errors).
- P_i Target customer service level for end-item i is are the minimum service levels that the customers want to perceive. Although service is a broad definition, we will use the service level definitions as defined in section 3.4.

Supply side

- a_{ij} Number of items i needed to produce one item j, j=1,2,…N. By defining this parameter the bill of material (BOM) can be represented and hence the supply chain network can be formulated. Only the processes and stock points upstream and till the CODP are modeled because planned stock will only occur here (section 3.5). Therefore, the CODP location per customer need to be known in order to aggregate the expected demand.

L_i The planned lead time of orders released for end-item i. More specific, this is the time needed to transfer the item from stock location i to stock location j and is includes the time needed for production (if applicable).

h_i Value added per item i during processing of an order for end-item i. This parameter is needed to determine the cost tied up in the inventory settings as proposed.

System logic

R Review period per stock point needs to be known per stock location. For an explanation of this term we refer to section 3.6. This parameter can be defined in the detailed input and output tab.

The number of periods/year is another input parameter SCOpE uses. The reason of having this parameter is that orders are generated over one year in order to determine the average inventory levels and the safety stock settings per stock location. To get a good comparison, all parameters should have the same time unit (i.e. time unit is days when the number of periods per year is 365).

The interest rate/year is needed to translate the total costs tied up in the inventory to the opportunity costs. This can be done by using the WACC percentage for the interest rate (see section 4.2.1 for a further explanation).

Make-to-stock or *Assemble-to-order* environment. Make-to-stock is referring to the situation in which end-items are made to stock. Assemble-to-order is assuming that the children of the end-items are made to stock and the end-items assembled from these children to order. This button will also start the optimization or evaluator process and hence must be selected after all the other settings are defined correctly.

Service criterion can be used to switch from the P_1-measure to the P_2-measure and vice versa. For the definition of these measurements we refer to section 4.2.2.

Simulation. This button will switch to a discrete event simulation in order to validate the analytical expression for the performance to the near-optimal calculations. It will check the formulas used.

Minimal stock in time ensures that the solution generated by the optimize procedure yields a solution where each stock point has at least this minimal stock planned for.

Design mode can be set on optimization or evaluator. We will elaborate these two modes in the next section which is related to the output parameters.

5.2 Output parameters SCOpE

The output of the SCOpE model depends on the design mode option. There are two options:

Optimization-mode. In this mode the near-optimal inventory asset deployment for a given network is determined, subject to the minimal stock in time constraint and the target service levels we want to achieve. This is done against minimal total costs which are comprising the pipeline costs, the raw material costs and the inventory costs, multiplied by the WACC to be able to compare these cost with other investment decisions. The average stock levels are given in quantities (fixed safety stock) and in number of time units that demand will be covered (dynamic safety stock). In order to define the average safety stock settings per stock location, we must deduct the average stock level with the average batch stock in the pipeline. Hence we have the following mutation: Average safety stock level stock point i = Average inventory level - ½ * R * $E[D_i]$.

Evaluator-mode. In this mode the performance of a given inventory asset deployment decision is determined. The user-specified stock levels are used to determine the overall system performance as well as the performance at each stock point.

5.3 Retrieving the input parameters in practice

The input parameters as defined in section 5.1 must be subtracted from multiple sources. An overview how we initially retrieve these parameters within NXP can be given as follows:

Input	Description	NXP information used	Source
N	The number of end-items taking into account	➢ Relation between die and 12NC subtracted from BOM structure	➢ SAP system
a_{ij}	The BOM structure	➢ CODP location per customer for a specific 12NC and the connections between the stock locations	➢ SAP system
$E[D_i]$	Expected demand per period for end-item i	➢ Forecast per customer per 12NC on a weekly basis. Average defined over the demand per CODP location over the next 13 weeks[7]. $\mu = \frac{\sum_{i=1}^{13} x_{0,i}}{13}$ with $x_{0,i}$ = the forecasted demand for period i performed at time 0.	➢ Available to promise files (including the FC figures) ➢ Link to CODP
$\sigma[D_i]$	Standard deviation of errors of forecast over a period for end-item i.	➢ We initially will use the standard deviation of the forecast to measure how widely values are dispersed from the average value. $\sigma = \sqrt{\frac{\sum_{i=1}^{13} (x_{0,i} - \mu)^2}{12}}$ with $x_{0,i}$ and μ as defined under $E[D_i]$.	➢ Available to promise files (including the FC figures) ➢ Sales order books
P_i	Targeted service levels	➢ The RLIP percentage per customer.	➢ BBSC ➢ Planners
L_i	The planned lead time of orders released for end-item i	➢ The time needed to transfer an item between two stock locations, captured in the planned lead time. This planned lead time within NXP is a combination of the production time, the movement time and the safety time to reach a 90% confidence interval.	➢ SAP system/ planning engine
h_i	Value added per item i	➢ Cost build up over the supply chain. Looking at the cost price per stock location.	➢ BU controller

From this overview we can conclude that information is needed from multiple sources before we are able to use the model. Furthermore, some information should be linked in order to get the right

[7] *We are estimating the average demand and the standard deviation and hence the official notation should be $\hat{x}$ and s instead of μ and σ.*

aggregated data. Whether the way we capture the input parameters is correct will be tested in chapter 6 and eventually be improved in chapter 7.

5.4 Modeling issues and assumptions SCOpE

By using SCOpE as a model for optimizing inventory levels over a network we have to realize that there are several modeling issues and assumptions to deal with in order to use SCOpE within NXP.

- Before using SCOpE the network structure must be know. The network downstream the CODP location will not be modeled implying that the customer is accepting the lead time needed to transfer the product from the CODP to the customer dock. SCOpE assumes that customers are aware of this and are placing orders according to this lead time. This implies that the CODP location must be set in line with the customer order behavior to get valuable outcomes.
- As described in section 4.3, NXP is able to set multiple CODP locations for one single end-product. Meaning that a modeled stock location can face a direct demand and an indirect demand simultaneously. The direct demand is generated by the customers with their CODP at this location. The indirect demand is generated by the customers with their CODP at a more downstream location. SCOpE is not directly supporting this phenomena and hence this implies that we have to introduce dummy nodes. These dummy nodes are virtually the same location and thus the lead time between the dummy nodes and the original node is set zero.
- The model assumes that all production locations can be represented by a planned lead time. Also NXP works with planned lead times representing the production time, the movement time and the safety time to reach a 90% accuracy of the provided planned lead time. This planned lead time is also used within NXP's planning engine and hence we see no implications of doing the same. Optimizing safety times is a different subject that falls outside the scope of this thesis.
- SCOpE assumes that lateral transshipments are not possible between stock locations. Also within NXP this does not occur.
- Demand that cannot be met instantly will be backlogged without having any lost sales. The general understanding is that this will also occur within NXP, although we cannot proof this.
- SCOpE ignores any finite replenishment capacities within the production processes.

5.5 Conclusion

In order to use SCOpE, information is needed related to the demand side, supply side and system logic side. Per parameter we decide what information within NXP is needed and how to use it. The following three parameters are less straightforward:

- *Expected demand:* The average forecast over the next 13 weeks is calculated per end-product based on the system forecast files.
- *Standard deviation:* The fluctuations of this forecast through time is calculated.
- *Lead time:* The planned lead time will be used which a combination of the production time, the movement time and the safety time to reach a 90% confidence interval (also used within planning engines).

The output SCOpE gives depends on the selected output mode:

- Optimizer: This mode provides the optimal inventory deployment for the modeled network under minimum costs while reaching the targeted service levels.
- Evaluator: This mode provides insight in the performance (i.e. service level that can be reached) of a given inventory asset deployment decision over a network.

We closed this chapter by providing some general assumptions when using SCOpE in practice. These assumptions can eventually limit the usability of SCOpE.

- CODP locations are known in advance and customers do not order within the lead time needed to transfer a product from CODP to customer dock.
- NXP uses multiple CODP locations for a single end product. SCOpE is able to support this by the introduction of dummy nodes with an incoming lead time of zero.
- The production and transportation times are represented by the planned lead time which includes a safety lead time. Optimizing these safety lead times is a different research area.
- Lateral transshipments are not possible, lost sales will not occur and capacity problems will be ignored.

Now we know how to use SCOpE, the next step in order to answer research question 2 is to test SCOpE in practice and to find out whether the results given are valid.

Chapter 6 Model testing

Now we know how to use SCOpE as outlined in the previous chapter, this chapter aims to test whether the SCOpE model is sufficient accurate for the purpose of determining the safety stock settings over the network. Moreover, we will identify the critical input parameters that should be improved to increase validity. To come to these improvement areas, the way of working is outlined in section 6.1 followed by the results of the validation and verification process in respectively section 6.2 and 6.3. The chapter will be closed with a conclusion in section 6.4.

6.1 Way of working

The overall purpose of model testing is to validate and verify the model used. *Validation* is concerned with determining whether a conceptual model is an accurate representation of the system under study. *Verification* is determining that a model performs as intended, i.e. debugging the computer program (Law & Kelton, 2000). The way of working relating to both steps can be described as follows:

- **Validation:** To validate the model to following steps will be performed (see Figure 6.1):
  1. We will run SCOpE under the same conditions as the real world system in the month May 2007 (the actual safety stock settings are used as input) and we will compare the model outcomes (i.e. perceived service) with the actual perceived service (i.e. RLIP%). This can be done by using the SCOpE evaluator mode.
  2. Differences between the service levels (evaluator vs. actual) can be grouped as follows:
     - $RLIP_{evaluator} > RLIP_{actual}$: With the actual safety stock settings over the network under analysis, the model calculates a higher service level than the actual reached service level in practice.
     - $RLIP_{evaluator} < RLIP_{actual}$: With the given safety stock settings over the network under analysis, the model calculates a lower service level than the actual reached service level in practice.
  3. The question occurring per group is whether the mismatch is caused by incorrect safety stock settings or by other factors occurring in the environment we are applying the model in. The

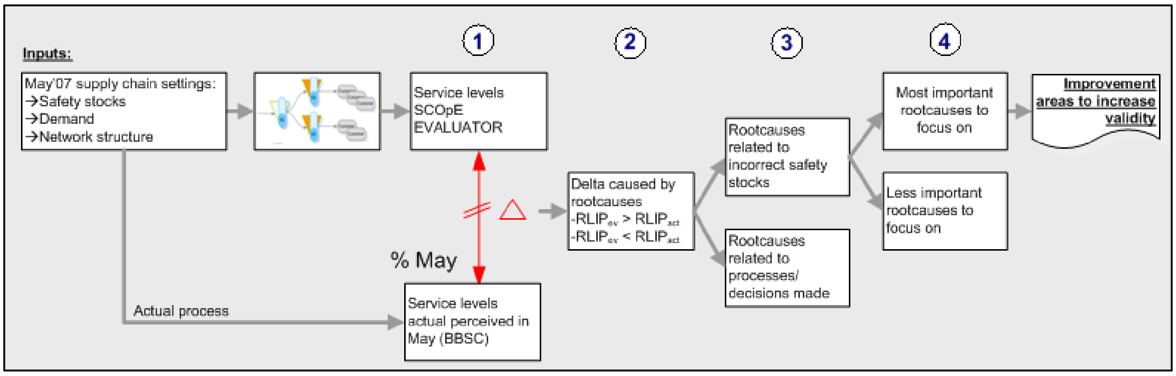


Figure 6.1: Process to find root causes for increasing the validity of SCOpE.

former will indicate that the SCOpE model should be improved in order to increase its validity, the latter will indicate that the processes within NXP can be improved.

4. Before improving all the root causes related to incorrect safety stock settings, we will focus on the most important root causes identified by planners. To be sure whether these root causes really have an impact on the safety stock settings or the service levels, a sensitivity analysis will be performed.

To perform this validation, a case study analysis will be used for the month May 2007. A case study is a type of research during which the researcher tries to gain a profound insight into one or several objects or processes that are restricted in time and space (Verschuren & Doorewaard, 1995). We selected six case studies within the MMS-PM which are all representative for this BL/NXP with respect to their production processes (customer specific vs. commodities; multi die; multi-source), customer behavior (multiple vs. single customers and customer programs and non-customer programs) and life cycle phase (mature). For more details of these case studies we refer to Appendix G. The selected case studies within MMS-PM are containing 2% of the end-products, 1% of the dies and are responsible for 7% of total BL sales.

MMS-PM is selected because they have a high inventory percentage (Appendix C) and the BL is highly committed in setting up a case study to increase the insights between inventory costs and service levels. Commitment is important because of the labor-intensive face-to-face interviews during analyses and to increase the creditability of the work (Verschuren & Doorewaard, 1995).

- **Verification:** During this process, results related to verification will also become visible.

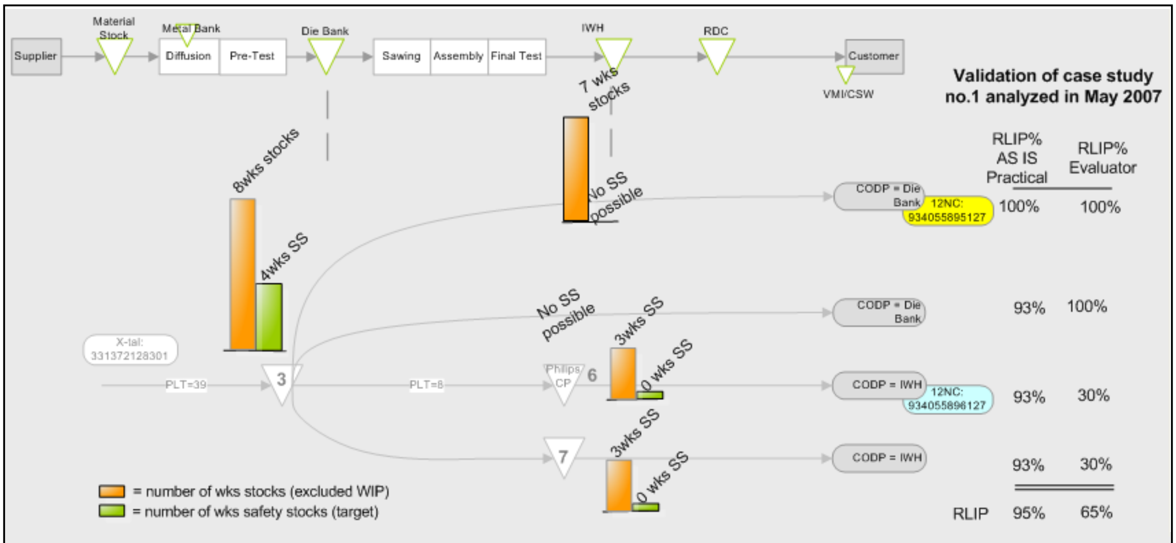
6.2 Validation

Now the overall process has been sketched, we can start the validation process. Step 1, 2 and 3 will be described in section 6.2.1: *Root cause analysis*. Step 4 will be described in section 6.2.2: *Sensitivity analysis*. In section 6.2.3 we will decide what the main improvement areas are in order to increase validity of SCOpE.

6.2.1 Root cause analysis

In the upper part of Figure 6.2 the validation results of case study no.1 are depicted in which we that the theoretical service level (evaluator mode shows 65%) is lower than the actual perceived service level in May 2007 (95%). The zero safety stock settings for the IWHs can be the cause for this effect. In practice, this mismatch is smoothed by the high stock levels within the supply chain (caused by batching and utilization) but also by a long order lead time (see Appendix H for more details).

In the lower part of Figure 6.2 the average service levels per case study with the main root causes for the differences are depicted. A detailed overview of the results related to the other case studies are given in Appendix I. In the next two subsections we will explain the different root causes related to $RLIP_{evaluator} > RLIP_{actual}$ (section 6.2.1.1) and related to $RLIP_{evaluator} < RLIP_{actual}$ (section 6.2.1.2) in more detail.



Case		RLIP as is (May'07)	RLIP evaluator	Main Rootcause
Case 1	331372128301	95%	65%	No SS at IWH, Order within LT, Utilization, Batching, Long order LT
Case 2	331373484301	82%	88%	No SS at IWH-CP, Increased utilization Allocation, Under-FC, Yield
Case 3	331371914301	90%	100%	Order within LT, under FC.
Case 4	331372326301	77%	82%	No SS at IWH-CP, Order within LT Batchin, Over-FC
Case 5	331373118301	64%	55%	No SS.
Case 6	331373583301	We are not able to model this case within SCOpE (see verification)		

Figure 6.2: **Upper part: Overview of the results of case study no.1 (see appendix H for more details)**
Lower part: The average results of the validated six case studies (see appendix I for the details per case study).

6.2.1.1 Root causes related to $RLIP_{evaluator} > RLIP_{actual}$

The first category of root causes are related to the phenomena that $RLIP_{evaluator} > RLIP_{actual}$. So, with the given safety stock settings over the network under examination, the model calculates a higher service level than the actual reached service level in practice. There are five main root causes mentioned of which under-FC and yield were seen as causes which have an impact on the validity of SCOpE. P_2 vs. RLIP measurement can be seen as irrelevant to focus on. Allocation and orders within lead time are seen as causes related to the environment that cannot be linked to safety stock settings.

1. **Allocation issue**

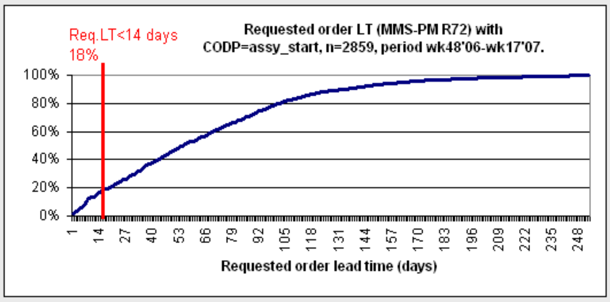
   Allocation applies to a situation in which the requested orders structurally cannot be fulfilled and is often caused by capacity limitations. Although allocation is the most often mentioned root cause for not reaching the predefined service levels, it should not be incorporated in the model because of several reasons. Fist; allocation issues are hard to predict and hence will lead to high safety stock settings in cases without an allocation issue. Moreover, allocation issues are mostly occurring for a longer period. In such a structural situation there is also no production capacity left to release safety stock replenishment orders because of the fact that customer orders are prioritized (section 4.3) and hence safety stocks will only have a limited effect. Second, in order to cope with allocation, planners will manually interrupt the system in order to limit the effect to the customers (e.g. shifting stocks, pre-builds, out-source etc). A last reason is that allocation is often caused by an under-forecast or by a lower than expected yield (quality issues). These two issues are mentioned as separate root causes (respectively no.4 and no.5).

2. **Order within lead time**

A requested lead time shorter than the actually needed lead time to transfer the product from the CODP location to the customer dock is a second main root cause for perceiving a lower actual service level. SCOpE assumes that this behavior will not happen (see assumptions 5.4). Not reaching the targeted service levels is not caused by wrong safety stock settings, but by a wrong supply chain settings (i.e. wrong CODP location). An example of this behavior/wrong setting is given in Figure 6.3.

In practice we identified that the requested delivery date will be frequently met because there can be planned stock within the SC between the CODP and the customer dock which is not taken into account in the model (also a reason for $RLIP_{evaluator} > RLIP_{actual}$). Furthermore, the requested delivery date can also be met via additional efforts of the planners in order to decrease the lead time (e.g. speed deliveries). Finally, the shorter order lead time can be met by using safety stock which was actually dedicated for a group of customers with their CODP location more downstream. This last option is only used when the planner foresees no risks of doing so (e.g. excess capacity to replenish the safety stock directly). Of course this last option is tricky because after doing so you are not able to guarantee the service level anymore for the group of customers the dedicated safety stock was actually for.

Based on this root cause we can conclude that the system settings, and more specific the CODP location, should be in line with the customer order behavior and that a wrong CODP location cannot be solved by increased safety stock settings. Hence, before using the SOCpE model, a CODP assessment needs to be performed. We will come back to this issue when discussing the application areas in a later stadium of this research.



18% of the orders is requested within the LT of 14 days. Theoretically speaking, the requested delivery date will not be met and thus the service will decrease. Hence, change the CODP at a strategic level based on:

- Is this a structural behavior?
- Is it caused by key customers?
- Can NXP take risks?

Figure 6.3: Proof that CODP settings are not in line with customer order behavior and hence automatically lead to a RLIP miss.

3. **P_2 vs. RLIP measurement.**
Another root cause for the perceived differences in service levels between the modeled and practical situation could be the difference of service measurement used (i.e. SCOpE uses the P_2-measurement while NXP uses the RLIP measurement). The inventory position can decrease in three different ways during a review period (Figure 6.4). In all situations we suppose that the number of order lines per time unit are the same and that we have a similar backlog at the end of the period resulting in similar P_2 service levels but different RLIP measurements (respectively high, medium, low). In the most left graph, the biggest orders are requested at the end of a period with the result that the P_2-measurement will be worse than the NXP RLIP measurement, and hence the P_2-measurement will be a too strong measurement. In the most right graph, the biggest order are requested at the beginning of a period with the result that the NXP RLIP measurement will be worse than the P_2-measurement and hence the P_2-measurement will be a too weak measurement. The graph in the middle represents the situation in which the NXP RLIP measurement equals the P_2-measurement. Looking at the actual situation of MMS-PM[8], we can conclude that the order quantity through time is equally divided because the 50% quantity is generally in the middle of the period under analysis. Hence we see no reason to put effort in changing the model's service measurement.

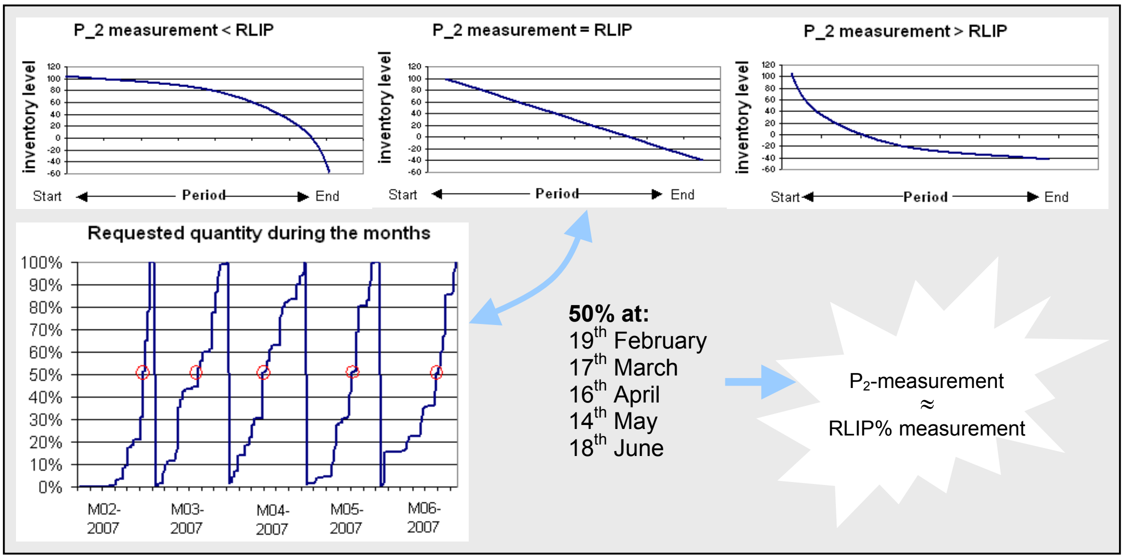


Figure 6.4: Proof that RLIP measurement equals P_2-measurement.

4. **Under-forecast**
Having an under-forecast is another reason for perceiving a lower service level in practice. Under-forecast refers to a situation in which the actual sales are higher than the forecasted sales. An under-forecast for a small period must be solved by sufficient safety stock within the supply chain and hence we need to be sure that we have the correct safety stock setting to cope with this issue. To do so, the average demand and the standard deviation must be as good as possible. A structural under-forecast must be solved by the demand managers and falls outside

[8] *We analyzed a representative mature product for MMS-PM, namely 12NC: 934003470215 (2N7002/SOT23/REELLP//)*

the scope of this thesis. Because the probability to have an under-forecast increases during the ramp-up phase, it is more difficult to use SCOpE in these situations.

5. **Lower yield**
   A fifth reason for perceiving a lower service level in practice than the model calculates is when the yield within a production step is lower than expected. The yield percentages are taken into account in the planning engine, but not the fluctuations. Hence, safety stock must be set to overcome the unpredictable fluctuations in this yield percentage. Currently SCOpE is not able to take this phenomena into account. A note is that it is not able to model the network downstream the CODP location and thus when a lower than expected yield is occurring at this part of the supply chain, the actual perceived service level will always be lower.

6.2.1.2 Root causes related to $RLIP_{evaluator} < RLIP_{actual}$

The second category of root causes are related to the phenomena that $RLIP_{evaluator} < RLIP_{actual}$. So, with the given safety stock settings over the network under examination, the model calculates a higher service level than the actual reached service level in practice. There are six main root causes of which high batch sizes and over-FC were seen as causes which have an impact on the validity of SCOpE. Order cancellations and rounding quantities will increase the perceived service levels but are seen as irrelevant by the planners to focus on. Utilization and long requested order lead time cannot be linked to incorrect safety stock settings.

6. **Increased wafer-fab utilization**
   A main root cause for perceiving a higher service level in practice than expected by the model, is caused by loading the wafer-fabs in order to perceive a higher utilization rate. To do so, management makes strategic decisions to start manual orders. Although this is mainly done for products with high demand prospects, it will lead to excess stock in the supply chain which will take over the safety stock function and hence a higher service level than expected can be reached. Although solving this root cause can only be done by higher management, this research shows the effect of loading fabs in order to increase utilization. Probably this is also one of the main reasons for the high inventory percentage within MMS-PM (see Appendix C).

7. **High batch sizes**
   A second root cause within this category are the high batch sizes within the production processes leading to higher service levels in practice than expected by the model. Because of high batch sizes, the probability that you will reach an out-of-stock situation decreases. This is caused by the phenomena that high batch sizes will lead to high replenishment orders and hence higher average stock levels that will take over a part of the safety stock function. Not taking this effect into account will result in a too high safety stock coverage and thus a non-optimal situation. Because the SCOpE model is currently not incorporating the batch sizes of the production processes, we can see this as an important improvement area of SCOpE.

8. **Over-forecast**
   Having an over-forecast will lead to excess stock within the supply chain and thus a higher service level can be met than calculated via the SCOpE evaluator mode under the same safety stock settings. Over-forecast will increase the service levels because of two reasons. First, because of dynamic safety stock settings the safety stock quantity is higher than needed. Second, because of the over-forecast there will be excess stock between the forecast and order driven part of the supply chain (i.e. at the CODP). An over-forecast which can be marked as structural must be solved by the demand managers and falls outside the scope of this thesis. An over-forecast for a small period has impact on the safety stock settings and hence the average demand and the standard deviation must be as good as possible.

9. **Long requested order lead time**
   A requested lead time longer than the actually needed lead time (time from CODP to customer dock) is a fourth main root cause for perceiving a higher actual service level. A longer requested order lead time will lead to more flexibility for NXP and hence a higher probability that the requested order delivery date will be met resulting in higher service levels. As already mentioned under the root cause 'within order LT', we should not adapt the model to this phenomena but we should be sure that the supply chain under analysis is a correct representation of the real world. Setting the correct CODP locations should therefore be done before we apply the SCOpE model. A structural longer order LT is an indication that the CODP location can be placed more upstream for at least a part of the customers.

10. **Order cancellations**
    Order cancellations will lead too excess stock within the supply chain and hence a higher service level can be met in practice. Because we are not able to predict the moment of getting an already started order cancellation or a customer return, it is not doable to incorporate this issue in the SCOpE modulation. Furthermore, the frequency of this root cause is very low.

11. **Rounding quantities**
    A last reason of perceiving a higher service level in practice than in the model situation is related to rounding quantities within the modeled supply chain. Rounding quantities will lead to excess stock within the supply chain and occur while starting up new batches. For example: when the minimum batch size is 10.000 with a rounding quantity of 1.000, an replenishment order of 11.000 will be started when the needed quantity is within the range [10.001….10.999]. We expect that this effect is minimal comparing it to the effect of the used batch sizes.

6.2.2 Sensitivity analysis

To find out whether it makes sense to reduce the root causes marked as relevant (improvements will probably increase validity) in the previous section, a sensitivity analysis will be performed (cf. step 4, Figure 6.1). The root causes marked as relevant to focus on were under- and over forecast, batching and yield fluctuations and will be further analyzed in section 6.2.2.1. In section 6.2.2.2 we will provide additional insights in the available trade-offs between costs and service by also performing a sensitivity analysis for other parameters SCOpE uses.

The sensitivity analysis contains a simple two echelon network. The base case with its default parameter settings is depicted in Figure 6.5 in which the IWH is the CODP location and thus the RDC and CSW are not modeled. At the bottom of this figure the optimal safety stock settings are depicted in order to reach a 90% service level. To get a good understanding of the dynamics within this network we will change one input parameter in the base case and calculate what the optimal safety stock settings should be over the network (optimizer mode). With this analysis the effect of the changed parameter on the safety stock settings will become visible. In some cases it makes sense to use the optimal safety stock settings of the base case as input in the evaluator mode and find out what the effect of changing an input parameter is on the perceived service levels (evaluator mode).

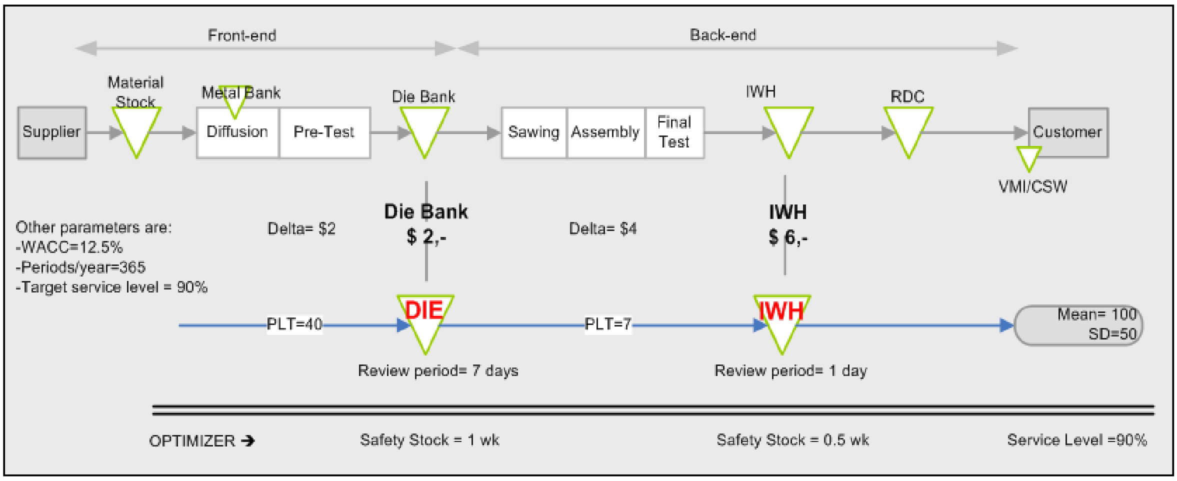


Figure 6.5: Base case used for sensitivity analysis to define improvement areas.

6.2.2.1 Sensitivity related to root cause parameters

The four root causes linked to incorrect safety stock settings by SCOpE and identified as relevant were under- and over forecast, yield and batching.

The effects of changing the demand and standard deviation

In section 6.1.2 we already indicated that an under- or an over-forecast will have an effect on the service level perceived or the safety stock levels within the supply chain. In case of an under-forecast we expect that the safety stock settings are too low (root cause no.4). In case of an over-forecast we expect that the safety stock settings are too high (root cause no.8). Under- and over-forecast can be analyzed by changing the demand and standard deviation.

Based on a sensitivity analysis we can draw the following conclusions (base case is a demand of 100 units/day and a standard deviation of 50 units/day):

- When we have an over-FC (Figure 6.6, upper left graph), the actual perceived service will indeed be higher than the target service level because the safety stock settings are too high (e.g. with $1500,- safety stock value we will reach a 99% service level instead of the targeted 90%).
- When we have an under-FC (Figure 6.6, upper right graph), the actual perceived service will indeed be lower than the targeted service level because the safety stock settings are too low (e.g. with $900,- safety stock value we will reach a 77% service level instead of the targeted 90%).
- When demand increases, the coefficient of variation[9] (CV) will decrease because the standard deviation remains equal. This results in a reduction of the needed safety stocks (Figure 6.6, lower left graph). Moreover, the ratio between the order-up-to level and safety stock also increases caused by the fact that the batch (pipeline) stock will increase ($\frac{1}{2}*R*\mu_D$) leading to a situation in which this batch stock will function as safety stock as well.
- When the standard deviation increases, the CV will increase because we did not change the average demand. This results in an increase of the needed safety stock (Figure 6.6, lower left graph). In the left part of this graph, we can even see that an extreme low standard deviation (so near a deterministic world) can lead to negative safety stock settings (in practice this will become zero) because the batch stock will completely take over the safety stock function.
- Interesting to see is that the Die quantity has a higher slope than the IWH quantity, caused by the fact that the Die stock is twice as cheap as the IWH stock.

Based on this analysis we can conclude that our expectation was correct.

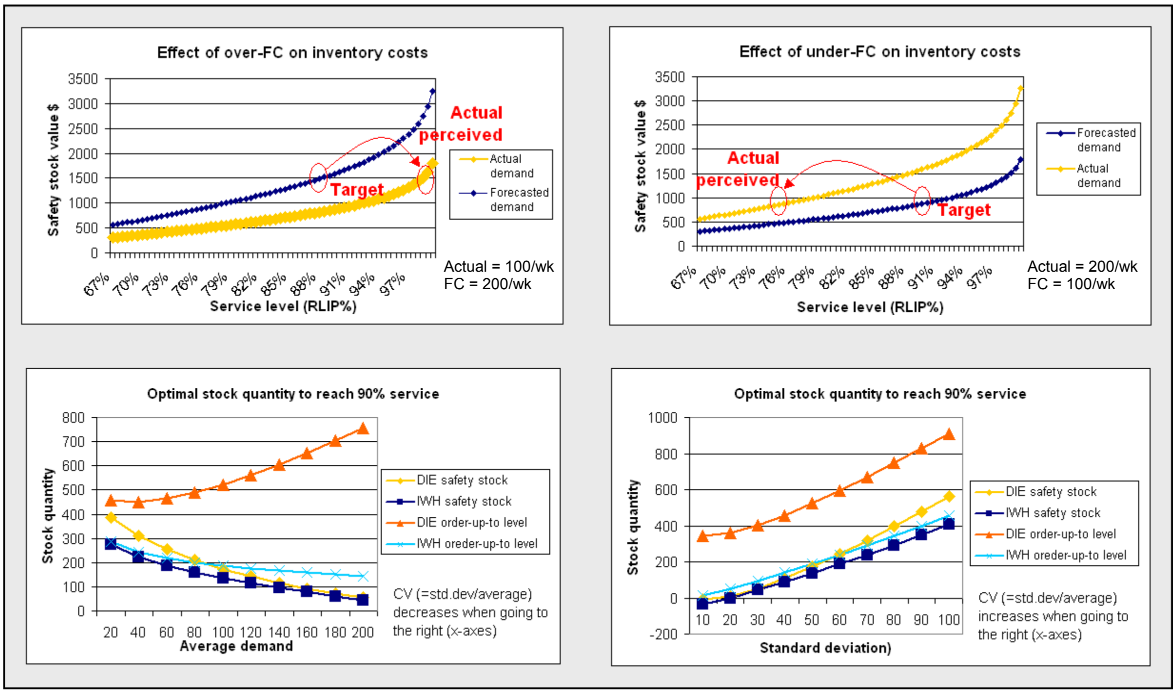


Figure 6.6: Effects of changing the demand and standard deviation on the needed stocks

[9] *Coefficient of variation (CV) is the ratio of standard deviation divided by the average demand over the same period.*

The effects of changing the planned lead time (front-end or back-end)

In section 6.1.2 (root cause no.5) we already indicated that a lower than expected yield will have a negative effect on the service levels perceived. Because the effective lead time is longer than the nominal lead caused by the lower than expected yield percentage, we can test this observation by changing the planned lead time we take into account.

A sensitivity analysis is performed in which the base case has a planned lead time of 40 days for the front-end and 7 days for the back-end. The planned lead time for the front-end is changed between 20 & 60 days and for the back-end between 2 & 12 days. The results are depicted in Figure 6.7 leading to the following conclusions:

- When the front-end planned lead time increases (i.e. >40days), the safety stock at the Die bank will increase in order to overcome the fluctuations in demand over a longer period. These fluctuations will be mainly covered by the Die bank safety stocks because these stocks are twice as cheap as the stock located at the IWH (upper left graph).
- When the back-end planned lead time increases (i.e. >7days), the safety stock at the IWH must increase in order to meet the service of 90%. Interesting is the phenomena that the decrease of the back-end planned lead time (i.e. <7days) leads to a shift of safety stock to more upstream locations because of the lower costs (and less riskier with respect to obsolescence) (lower left graph).
- When the safety stocks are already set (upper right and lower right graph), an increase or decrease of the planned lead time related the front-end or back-end will have a direct effect of the service levels that can be provided to the customers. A 50% increase of the planned lead time in the front-end (e.g. 40→60days leads to service level reduction from 90%→87.5%) is less problematic than the same increase at the back-end (e.g. 7days→10.5 days leads to service level reduction from 90%→86.3%). The reason for this is as follows: Because of this increase of

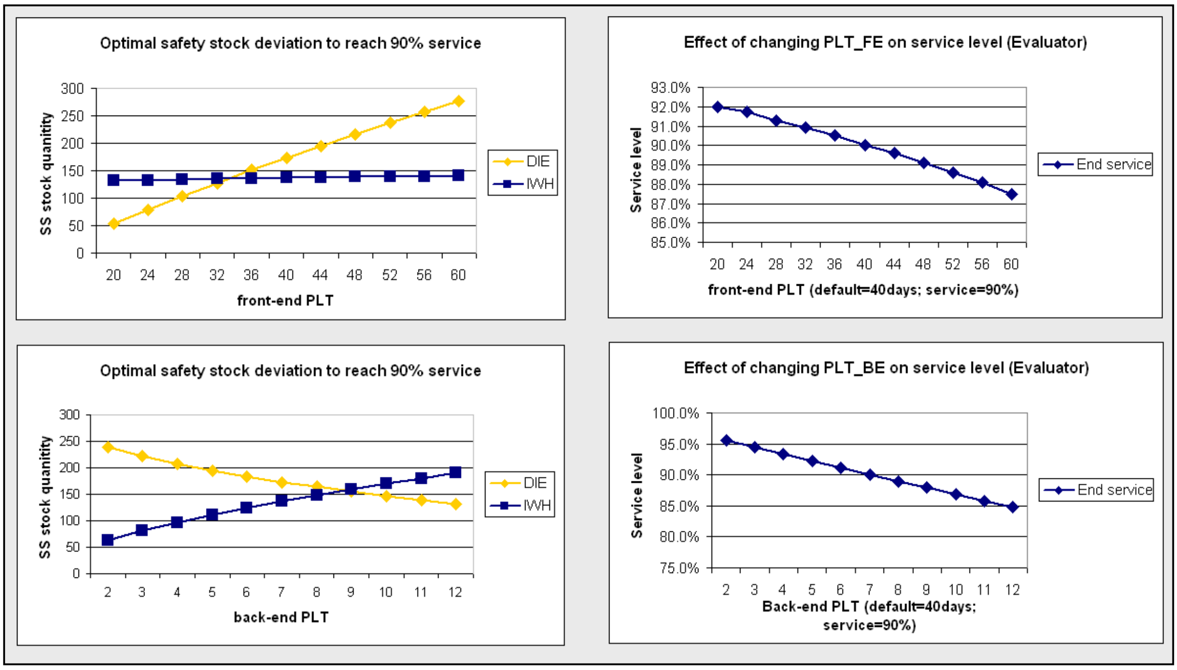


Figure 6.7: Effects of changing the planned lead time on the needed stocks

planned lead times, the safety stocks at both stock points are insufficient to give a 90% service to the customer. When only the safety stock at the Die Bank is insufficient compared to an optimal situation (e.g. when the planned lead time at the front-end suddenly increases), it will not always have a direct effect on the customer service because there is pipeline and safety stock between this stock point and the CODP. When the safety stock at the IWH is insufficient compared to an optimal situation (e.g. when the planned lead time at the back-end suddenly increases), given the fact that the IWH is also the CODP location, will have a direct impact on the perceived customer service.

Based on this analysis we can conclude that our expectation was correct.

The effects of changing the review periods (front-end or back-end)

In section 6.1.3 (root cause no.7) we already indicated that high batch sizes will lead to a reduction of safety stocks within the supply chain. The effect of batching can be analyzed by changing the review period because literature states that also high review periods will take over a part of the safety stock function (Van der Heijden & Diks, 1999).

A sensitivity analysis is performed in which the base case has a review period of 7 days for the front-end factories and a review period of 1 day for the back-end factories. When changing this setting respectively between 2 & 12 days and between 1 & 8 days we get the results as depicted in Figure 6.8. Related to these graphs we can get the following insights:

- ➢ When the review period of the front-end (left graph) increase, the safety stock quantity at the Die bank will decrease while the order up to level will increase. The reason is that the batch stock will take over the safety stock function.
- ➢ When the review period of the back-end (right graph) increase, the safety stock quantity at the IWH will decrease while the order up to level will increase. The reason is that the batch stock will take over the safety stock function. At the same time the Die stock will increase because it is cheaper to locate stock at this location.

Based on this analysis we can conclude that our expectation was correct.

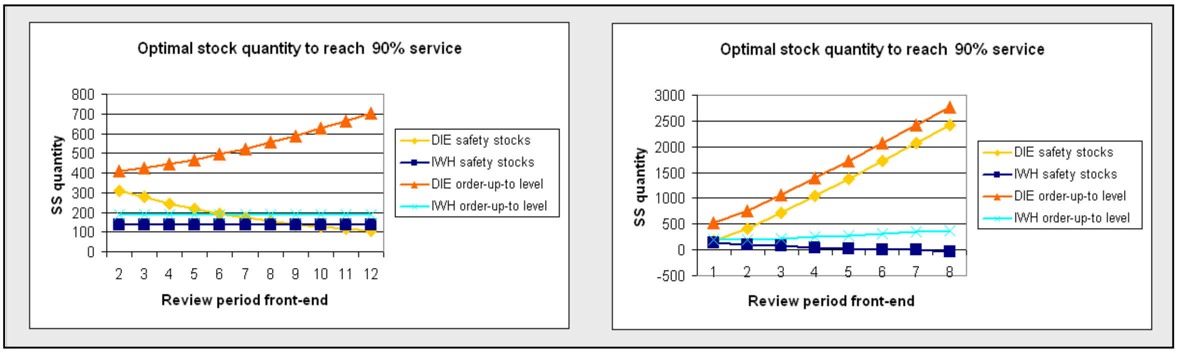


Figure 6.8: Effects of changing the review period on the needed stocks

6.2.2.2 Sensitivity related to other parameters

Within this category sensitivity is performed on two parameters that are not identified as root causes for mismatches during validation, namely the targeted service level and the value build up through the supply chain. It provides additional insights in the available trade-offs between costs and service.

The effects of changing the targeted service level

When changing the service level percentage, we expect that the safety stocks will increase when the service level targets will increase as well.

A sensitivity analysis is performed in which the base case has a service level of 90%. The results are depicted in Figure 6.9. Related to these graphs we can get the following insights:

- ➢ Increasing the service level with ß% will lead to a more than ß% increase of safety stock costs (left graph). Hence, the service level NXP wants to provide to their customers must be a strategic choice and will have a high impact on the inventory costs.
- ➢ Decreasing the service level will lead to negative safety stock settings at the Die bank (right graph). This is caused by the fact that the batch stocks are relative high (because of the high review period in the front-end of 7 days) and the service level is not extremely high. In such a situation, the batch stock will take over the buffer/safety stock function. In practice, the safety stock can never be negative and thus the safety stock will be set 0.

Based on this analysis we can conclude that our expectation was correct.

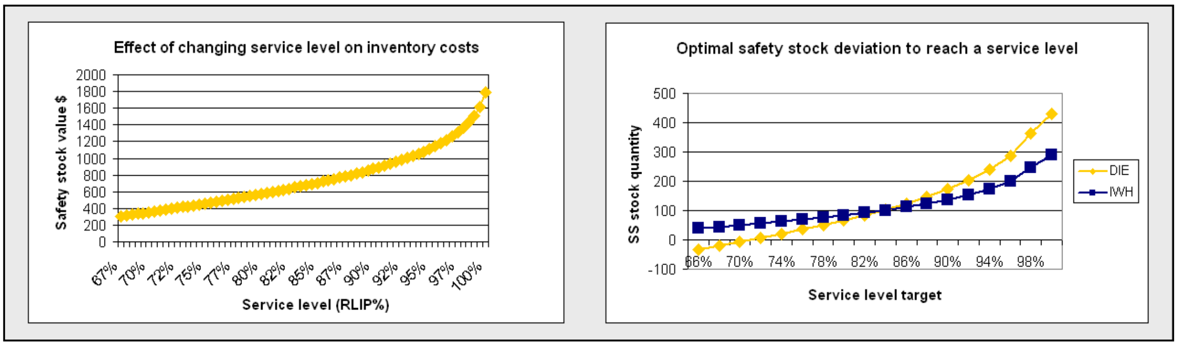


Figure 6.9: Effects of changing the service level on the needed stocks

The effects of changing the value build up

When increasing the value build up when going downstream in the supply chain, we expect that the safety stocks will reallocated to a more upstream location because this will be cheaper.

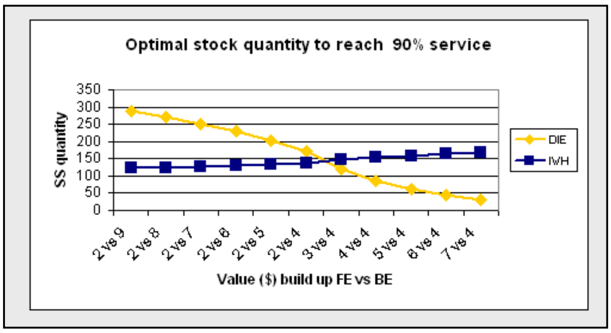


Figure 6.10: Effects of changing the value build up on the needed stocks

A sensitivity analysis is performed in which the base case has a stock value of $4,- at the Die bank and a stock value of $6,- at the IWH. So the value build up through the supply chain is respectively $4,- for the front-end (FE) and $2,- for the back-end (BE). We changed this proportion FE:BE (4:2) to a higher value build up in the FE (e.g. 7:4) and to a higher value build up in the BE (e.g. 2:9). The result is depicted in Figure 6.10 from which we can get the following insights:

- When there is more value added at the back-end compared to the base case situation (e.g. 2 vs. 9), the safety stock shifts to a more up-stream location. In this case a shift from IWH to the Die bank occur.
- When the most value is added at the front-end compared to the base case situation (e.g. 7 vs. 4), the safety stock shifts to a more down-stream location. In this case a shift from Die bank to the IWH occur.

Based on this analysis we can conclude that our expectation was correct.

6.2.3 Improvement areas to increase validity

Related to the root cause analysis (section 6.2.1) we identified four root causes as relevant to focus on in order to increase validity. These were under- and over forecast, yield and batching. Via a sensitivity analysis in section 6.2.2 we proved that:

- An over- or an under- forecast indeed will lead to higher or lower safety stock settings than actually needed. This effect is reinforced when having dynamic safety stocks.
- When the standard deviation increases, the needed safety stock will increase as well.
- Higher lead times than expected will indeed lead to an increase of the needed safety stocks in order to overcome the fluctuations of demand over a longer period. This effect is similar to the situation in which the yield percentage decrease because in that situation the effective lead time is longer than the nominal lead.
- An increase of the review period will indeed decrease the needed safety stock settings because the pipeline stock will take over this function. This effect is similar to a situation in which batching occurs.

Hence it makes sense to focus on the following root causes to increase the validity of SCOpE:

1. Average demand: This parameter is related to the under- and over-FC and hence we need to find a way to get the best representation of the expected demand in the future.
2. Standard deviation: This parameter is also related to the under- and over-FC and hence we need to find out what the best way is to capture this parameter.
3. Yield fluctuations: Currently this parameter is not taken into account and hence SCOpE need to be adapted.
4. Batching: Currently this parameter is not taken into account and hence SCOpE need to be adapted.

6.3 Verification and user friendliness

During the validation process we identified several bugs that can be linked to the verification process:

- A single echelon model like case study no.6 cannot be modeled.
- When you get a floating point error (i.e. optimize while demand is zero), you have to close SCOpE and restart it again in order to use the model.

- A low mean and standard deviation for an aggregated group of customers in relation to the other aggregated groups gives an error. After some programming changes by Prof. Dr. Ir. Ton de Kok, this bug is solved in a newer version of SCOpE.

To complete the assessment of SCOpE, we several improvements related to the user friendliness can be given. These improvements were identified during the validation and verification process and will give valuable inputs for a latter stage of this research in relation to implementation. The main improvements are as follows:

- A possibility within SCOpE to upload networks automatically (i.e. using the BOM instead of building the network within an editor like Notepad) will reduce the time needed for modeling and besides that will avoid flaws because the editor is highly sensitive for spacing.
- An extra column in the input/output tab should be added in which the transformation from order-up-to levels to safety stock settings is done automatically.
- The detailed input/output tab should be able too show long numbers as well. Currently the cells are too tight and hence not all figures can be read completely.
- The insights of the users will be increased when the outputs of the optimizer will be showed in the network as well instead using tables only.
- The detailed input/output tables should be linked to other programs (e.g. spreadsheets) to download the results or upload the input parameters.
- In order to model a simple case study, data is needed from 8 different files which has to be linked together in order to get the needed information. In order to do so we used within Excel the VLOOKUP function for linking the right information together as well as the pivot table function in order to get the right aggregated data. This manual work can be a bottleneck in a latter stage of this project and hence an integrated environment is advisable.

6.4 Conclusion

In this chapter answered research question 2.2, namely: “How to validate the SCOpE model in a practical environment and what input parameters can be identified as critical and hence should be improved to increase validity?”. We found that in order to increase the validity of SCOpE we should focus on the following four critical parameters:

1. *Average demand:* This parameter is related to the under- and over-FC and hence we need to find a way to get the best representation of the expected demand in the future.
2. *Standard deviation:* This parameter is also related to the under- and over-FC and hence we need to find out what the best way is to capture this parameter.
3. *Yield fluctuations:* Currently this parameter is not taken into account and hence SCOpE need to be adapted.
4. *Batching:* Currently this parameter is not taken into account and hence SCOpE need to be adapted.

Validation is done via running SCOpE under the same conditions as the real world system in the month May’07 (the actual safety stock settings are used as input) followed by a comparison of the model outcomes (i.e. perceived service) with the actual perceived service (i.e. RLIP%). This process is depicted in Figure 6.11 and is performed for six representative case studies (die-12NC combinations) within MMS-PM with respect to their production processes (customer specific vs. commodities; multi die; multi-source), customer behavior (multiple vs. single customers and customer programs and non-customer programs) and life cycle phase (mature). The critical parameters were found as follows:

- Eleven root causes were identified related to the perceived differences between the model and actual service levels. Of which:
  - Four root causes were linked to the current processes or current decisions made within NXP and hence cannot be solved by increasing or decreasing the safety stock settings but only by correct capacity allocation, management decisions or correct CODP locations.
  - Seven root causes were linked to incorrect safety stock settings are divided in relevant and less relevant.
    - The less relevant root causes are the order cancellations and returns, the rounding quantities and the P_2 vs. RLIP measurement. We will not focus on these root causes to increase the validity of SCOpE because the occurrence is low and the effect can be seen as minimal compared to the other root causes (based on planners experience).
    - The relevant root causes are under-FC, over-FC, yield fluctuations and batching. Via a sensitivity analysis we proved that these root causes indeed have an impact on the safety stock settings or the perceived service levels. And therefore it is recommended to focus on these parameters in order to increase the validity of SCOpE. This will be done in the next chapter.

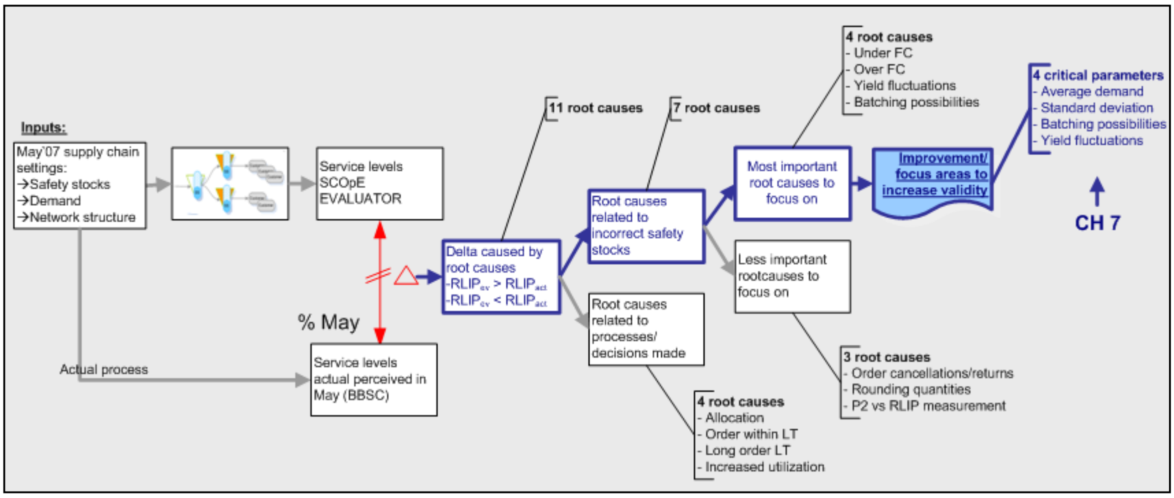


Figure 6.11: Process we followed to select the critical parameters to focus on in order to increase the validity of SCOpE.

During the sensitivity analysis we also gained additional insights in the available trade-offs between costs and service. The most important observations are:

- An over- or an under- forecast will lead to respectively higher or lower service levels than expected. This effect is reinforced when having dynamic safety stock settings.
- When the standard deviation increases, the needed safety stock will increase as well.

- Higher lead times than expected will lead to an increase of the needed safety stocks in order to overcome the fluctuations of demand over a longer period. This effect is similar to the situation in which the yield percentage decreases because in that situation the effective lead time is longer than the nominal lead. A decrease of the back-end lead times will shift the stocks downstream because of the lower costs involved.
- An increase of the review period will decrease the needed safety stock settings because the pipeline stock will take over this function. This effect is similar to a situation in which batching occurs.
- Safety stocks will be moved upstream when the most value is added downstream.

Related to the verification and user friendliness of SCOpE we found that a single echelon model cannot be modeled within SCOpE. Moreover, SCOpE is not directly usable by planners because the supply chain modeling in the current SCOpE version is too complex, user friendliness too low and data gathering might be too time consuming.

Chapter 7 SCOpE improvements

In the previous chapter we indicated four critical parameters that will probably increase the validity of SCOpE when captured in the most accurate way. These were: improve the way of taking into account the average demand and standard deviations, incorporate yield fluctuations, and incorporate batching possibilities. The yield fluctuations will be kept out of the scope of this thesis and will be solved by Prof. Dr. Ir. Ton de Kok separately. In section 7.1 we will give a methodology how to incorporate batching within SCOpE. In section 7.2 and 7.3 we will respectively deal with the best way of taking into account the average demand and standard deviation. It should be underlined that model testing should be done again after the improvements are made. This is in line with the interactive character of the research approach defined in Chapter 3. Therefore, in section 7.4 we will test whether the improvements made are making sense and thus will decrease the perceived delta between the modeled and the actual situation. This chapter will be closed by a conclusion in section 7.5.

7.1 How to incorporate batching

Batching is the phenomena in which demand is aggregated in order to be able to perform a production step more efficient (Economic order quantity, EOQ) (Silver *et al.*, 1998). Batching can be seen as an important parameter to incorporate in the model because when batch sizes (or lot sizes) are higher than the expected demand, this excess stock can take over the safety stock function (cf. section 4.3).

E[D] : Expected demand per day. For the front-end factories we aggregate the daily demand because a die can be used for multiple end-products.
MOQ : Minimum Order Quantity. Can be seen as the minimum batch size.
$R_{default}$: Review period in days. The time between successive planning periods.
R_{new} : The new review period with the batch size incorporated.

If MOQ/E[D] > $R_{default}$
Then R_{new} = MOQ/E[D]
Else R_{new} = $R_{default}$
End if;

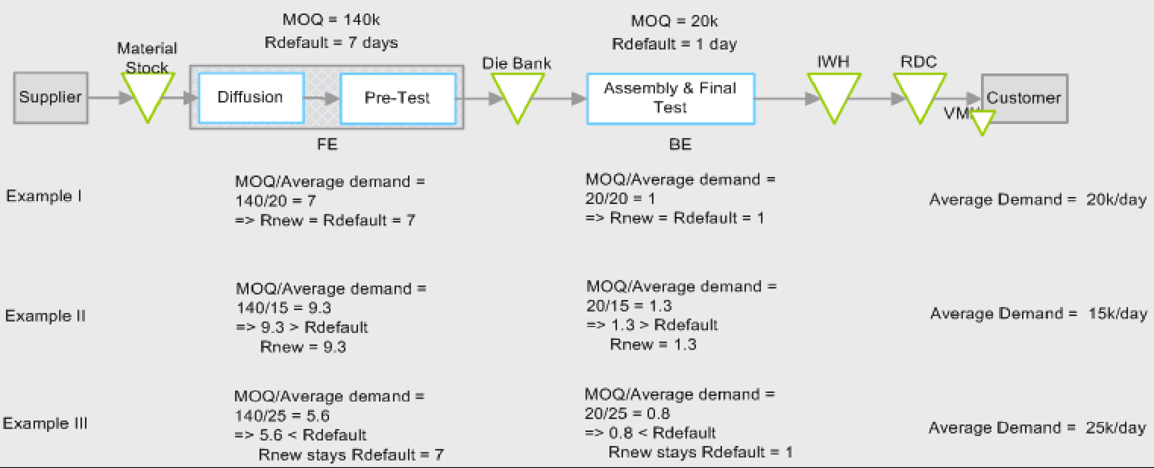


Figure 7.1: Example of how the review period must be adapted to incorporate batching.

Within NXP, the manufacturing orders released to the front-end and back-end factories are subjected to minimum order quantities (MOQ) and rounding quantities (RQ) in which RQ<<<MOQ generally holds. The MOQ can thus be seen as the minimum batch size.
During the sensitivity analysis (section 6.1.3) we already proved that high review periods will take over a part of the safety stock function. Therefore, we suggest to incorporate batching possibilities by increasing the review periods in those situations in which the demand during a review period is less than the batch size. When the demand during a review period is larger than the batch size, no excess stock will occur because then MOQ+k*RQ will lead to a batch size that equals the demand. Whether the MOQ equals the EOQ is another research subject and will be kept out of the scope of this thesis. The logic and an example is given in Figure 7.1.

7.2 How to determine the future demand

The average future demand can best be determined based on the monthly generated forecast. NXP generates three types of forecasts, namely:

- *Statistical Forecast*[10]: This forecast is generated via extrapolation models and uses analytics or statistics in determining the forecasted sales per month. Methods used are the literature based forecasting methods like moving average, exponential smoothing, double exponential smoothing included trend and seasonal characteristics (Silver *et al.,* 1998). The forecasts per end-product (12NC) is generated per month and is equally divided over the weeks within this month. Every month, the forecast is updated with respect to the most updated market insights.
- *System Forecast*: The statistical forecast is increased when the future order book exceeds the statistical forecast figure in a specific month. Else, the statistical forecast figure becomes the system forecast for that specific month.
- *Business Line Forecast (BL FC):* The BL FC is retrieved by increasing the system forecast by market insights. These market insights are based on subjective forecast methods performed by the Business Line. Common known methods are the Delphi method (use insights of a group of experts to express their opinions about customer demand), customer surveys and sales force composites (sales force obtains information regarding latest customer preferences) (Silver *et al.,*1998). The BL FC is the primary input in the system. Hence, orders are released and the safety stock is calculated (in case of dynamic safety stock) based on this forecast.

Related to NXP, the BL FC is the best information available of future demand at a certain time and thus using this figure as an input parameter seems logic. When using SCOpE at week t, we will calculate the average forecasted demand over the period t+4…t+16. The first four weeks are excluded from the sample because in these weeks the orders are already placed and thus no forecast occurs anymore. A period of 13 weeks is used because the average supply chain throughput time is approximately the same. Hence we get the following improvement over the way of measuring as indicated in section 5.3.

$$\mu = \frac{\sum_{i=5}^{17} x_{0,i}}{13} \quad \text{with } x_{0,i} = \text{the forecasted demand for period i performed at time 0.}$$

[10] Statistical forecasting is replaced by Manual Application Forecasting for more customer or application specific businesses. Within MMS, statistical forecasting is used.

Although we will use the BL FC as an input, an accurate forecast is essential in order to avoid high inventory levels (Van der Heijden & Diks, 1999). When this is not the case, wrong decisions will be taken (cf. garbage in, garbage out syndrome, Silver *et al.*, 1998) resulting in having too much stock of item x and too less stock of item y. This will lead to a bad service and manual interventions by the planners. We will not elaborate on improving the forecasts, although, improving the forecast should be one of the focus areas in order to get an efficient supply chain.

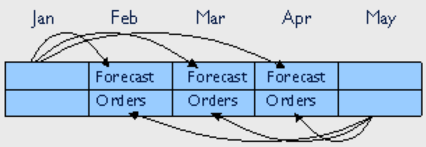
7.3 How to determine the standard deviation of future errors

In this section we will determine the best way to capture the standard deviation of future errors. We start in section 7.3.1. with an explanation how to calculate the standard deviation based on the perceived forecast errors. We will continue by explaining three experimental situations used in order to predict the forecast errors of the future based on the historical figures (section 7.3.2 till 7.3.4). These experimental situations are performed chronologically, implying that the next experimental situation is introduced to overcome the problems we faced in the previous experimental situation.

7.3.1 From FCACC to a standard deviation

The standard deviation is representing the deviation of the forecast errors over a period (cf. section 5.1), although, during testing we initially defined the standard deviation as the measure how widely values are dispersed from the average value (cf. section 5.3). The main problem of using this measurement is that we do not take into account the forecast errors. Moreover, the calculated standard deviation will be extremely low because the forecast is a relatively straight line and hence the deviation to the average decreases.

Silver *et al.* (1998) are providing a method to transfer the mean average deviation (MAD) to a standard deviation (Figure 7.2). The MAD equals the forecast error (=1-FCACC) which is a commonly used measurement within NXP. In this way we are able to determine the standard deviation based on the perceived forecast errors (1-FCACC) and thus meeting the pure definition with respect to the input parameters of SCOpE. The main concern while using this FCACC measurement, is that the forecast error can only be calculated afterwards.



FCACC M2-4 is calculated in May (M5), via

$$FCACC_{2-4} = 1 - \left(\frac{\left| \sum_{t=2}^{t=4} A_t - \sum_{t=2}^{t=4} F_{0,t} \right|}{\sum_{t=2}^{t=4} A_t} \right)$$

with:

A = Actual requested orders
F = Forecasted orders (BL FC)

Via the mean average deviation (MAD) we can define the standard deviation via the following method Silver *et al.* (1998):

$$\sigma_{month2-4} = \sqrt{\frac{\Pi}{2}} * MAD = 1.25 * (1 - FCACC_{month2-4}) * \mu_{actual\_requested\_order}$$

Figure 7.2: Explanation of the way to determine the standard deviation based on the FCACC.

7.3.2 Experimental situation I

In order to define the best estimator for the standard deviation we will face in the future, an experimental situation is set up by using the actual and forecasted sales from a period in the past (M7-2006 till M6-2007). With this data set we are able to test whether a certain method will provide us a good estimator for the standard deviation of the future, in which the future is a period in the chosen data set. This will be done on end-product (12NC) level because safety stocks are also set per end-product. An example related to the given data set is as follows: Suppose it is M12-2006 and we want to have an estimator of the standard deviation of the future (so M1-2007 and further). The target standard deviation is calculated via the MAD measurement based on the actual sales and forecasted sales in the months M1-2007 till M3-2007. The estimated standard deviation is only based on the figures we actually have in M12-2006 (i.e. the historical actual sales, and the historical and future forecasts per month).

To make a comparison between the targeted standard deviation and the estimated standard deviation, the coefficient of variation (CV) is used. The CV is the ratio of standard deviation divided by the average demand over the same period and is used to make an equal comparison that is not affected by the magnitude of the demand values (Silver *et al.* 1998). The following hypothesis will be tested:

$$H_0 : CV_{estimator\_method\_X} = CV_{target}$$

$$H_1 : CV_{estimator\_method\_X} \neq CV_{target}$$

We want to proof the H_0 hypothesis and will accept a difference of 10%, and thus we have:

$$\left|CV_{estimator\_method\_X} - CV_{target}\right| \leq (k * CV_{target}) \text{ in which acceptance margin k=10\%}$$

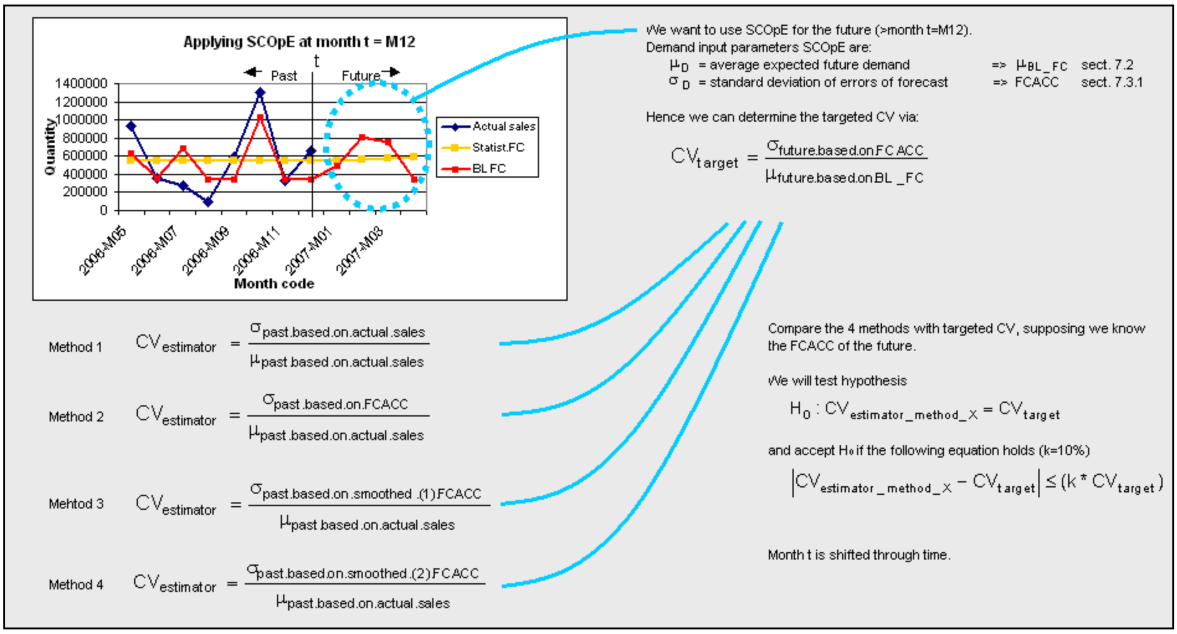


Figure 7.3: Visualization of the four different methods used within experimental situation I in order to estimate the standard deviation of the future based on actual sales and forecast errors from the past.

Four different methods are used to test whether H_0 is valid (Figure 7.3):

Method 1: At time t we compare the $CV_{estimator}$ with the CV_{target}. $CV_{estimator}$ is determined based on the standard deviation and the average sales of the historical actual sales over the last 6 months before time t. This CV can be compared with the CV_{target} calculated for the months later than t.

Method 2: At time t we compare the $CV_{estimator}$ with the CV_{target}. The $CV_{estimator}$ is determined based on the average perceived FCACC over the months t-6 till t-1 in combination with the MAD calculation, divided by the average actual sales over these 6 months in the past. This CV can be compared with the CV_{target} calculated for the months later than t.

Method 3: At time t we compare the $CV_{estimator}$ with the CV_{target}. This method is similar to method 2 with the difference that the FCACC over the months is smoothed because method 2 is highly sensitive for the peaks in the FCACC in the past which occur often (cf. Figure 7.4). Smoothing is done in the following way: 1) A perceived FCACC in the range [0;49%] will become 25%. 2) A perceived FCACC in the range [75%;100%] will become 80%. 3) A perceived FCACC in the range [50%;74%] will become 60%.

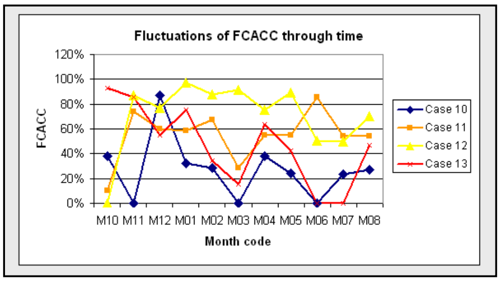


Figure 7.4: Visualization of the FCACC through time

Method 4: Same as method 3 except the smoothing: 1) A perceived FCACC in the range [0;49%] will become 10%. 2) A perceived FCACC in the range [75%;100%] will become 75%. 3) A perceived FCACC in the range [50%;74%] will become 50%.

Because at least need 6 months of history data and 3 months of future data when setting t are needed, and NXP only has a forecast history of 12 months available, H_0 can be tested for only three different months (namely t=M1;M2;M3). This is done for the 19 different mature end-products out of the six case studies as used during model testing (chapter 6). Hence we have n=3*19=57 comparisons per method under analysis. The results are as follows (Figure 7.5):

- The H_0 hypothesis of method 1, 2, 3 and 4 is only accepted in respectively 10%, 3%, 5% and 14% of the comparisons made and the acceptance margin is far above the current used 10%.
- Therefore we can conclude that we are not able to predict the forecast errors of the future based on the sales and perceived forecast errors in the past.

Reasons for the rejection of H_0 are as follows:

- The FCACC through time is very unstable (Figure 7.4).
- Each method is only tested during three moments in time. This is caused by the fact that NXP only stores their forecast figures of the last 12 months.

In order to cope with these concerns, a second experimental situation is set up in section 7.3.3.

Total case 1-19	Method 1	Method 2	Method 3	Method 4
% of situations that accept H_0	10%	3%	5%	14%
Average acceptance margin k to accept H_0	128%	81%	85%	96%

Figure 7.5: Results of the methods used within experimental situation I.

7.3.3 Experimental situation II

To overcome the limited data set available as discussed in experimental situation I, an option is to determine the CV of a specific 12NC based on the actual sales of which more than 12 months historical data is available. We expect that the sales fluctuations through time are representative for the fluctuations we will face in the future (Figure 7.6). The advantage of this method is the large data availability of the historical sales.

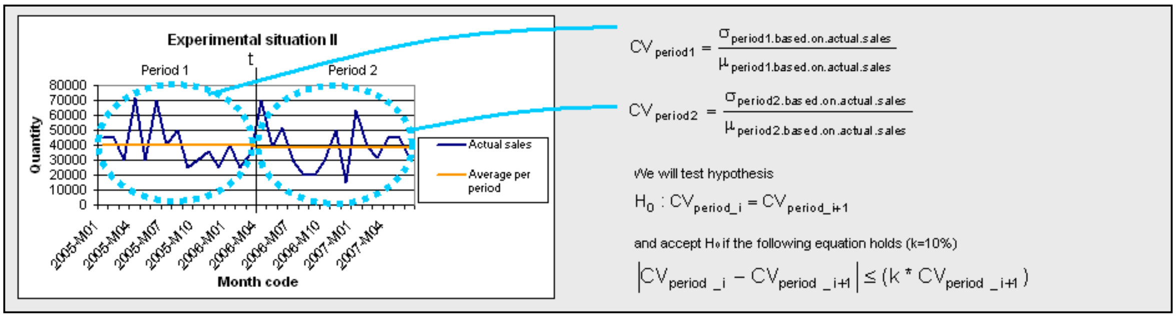


Figure 7.6: Visualization of the methods used to estimate the standard deviation of the future within experimental situation II.

The hypothesis we test is as follows:

$$H_0 : CV_{period\_i-2} = CV_{period\_i-1}$$

$$H_1 : CV_{period\_i-2} \neq CV_{period\_i-1}$$

We want to proof the H_0 hypothesis and will accept a difference of 10%, and thus we have:

$$\left|CV_{period\_i-2} - CV_{period\_i-1}\right| \leq (k * CV_{period\_i-1}) \text{ in which acceptance margin k=10\%}$$

When H_0 holds, we are able to estimate the standard deviation of the future by using the CV calculated from the past, via: $\sigma_{future.period} = CV_{previous\,period} * \text{average BL forecast}$. We again used the 19 mature products from our case studies and a period length of 15 months has been used to avoid the effects of business cycles (Silver *et al.,* 1998). The results are as follows (Figure 7.7):

- ➢ The H_0 hypothesis is accepted in 12% of the comparisons (n=19). Furthermore, the average k needed to accept H_0 is approximately 75% and thus far above the currently set acceptance margin of 10%.
- ➢ Therefore we can conclude that we are not able to use sales fluctuations of the past for the fluctuations we are going to perceive in the future.

The reason for the rejection of H_0 can be as follows:

- ➢ A specific end product fluctuates highly through the time. This is probably caused by the highly fluctuating business environment NXP is in.

In the next experimental situation we will look at an aggregated level in order to make the CV less dependable on fluctuations or business cycles in the past, leading to incorrect estimators.

Total case 1-19	Exp.sit.II
% of situations that accept H_0	12%
Average acceptance margin k to accept H_0	75%

Figure 7.7: Results of the method used within experimental situation II.

7.3.4 Experimental situation III

Because we are not able to develop an accurate method to estimate the correct standard deviation of the forecast errors on end-product level (experimental situation I & II), a third option is to determine a CV that holds for all end-products with similar market/product characteristics. This CV can be linked again to the BL FC of a specific end-product. The result is depicted in Figure 7.8 and the sorts are based on quantitative analysis in combination with the experience of the planners. The sorting steps done are now described in more detail.

Sort 1
First we sort all MMS-PM end-products based on their main article group (MAG), namely R72-BiPolar, R73-PowerMos and R79-PowerSolutions. This is done because the technology used differs per MAG which has an impact on the life cycle length. Moreover, the planning teams are also assigned per MAG code.

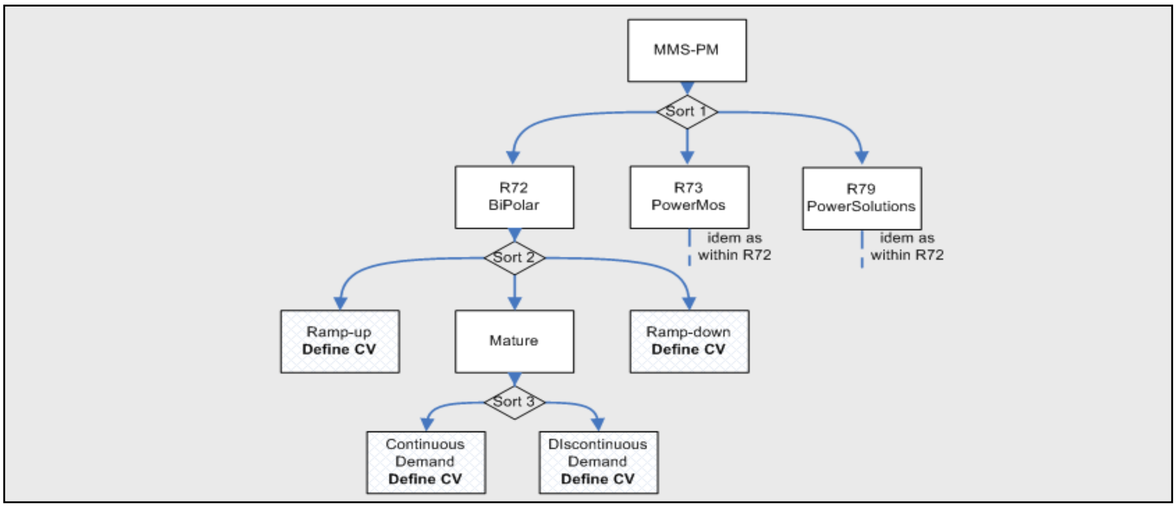


Figure 7.8: Overview of the used sorting tree in order to define a representative CV based on product/market characteristics.

Sort 2
Within each MAG, the end-products can be sorted according to their life cycle phase (ramp-up, mature, ramp-down) because it is generally known that during the mature phase the market will be more stabilized with respect to growth, technology changes, and the number of market segments (Silver *et al.,* 1998). This will be done based on the actual sales figures per end-product of the last 30 months[11].

- *Ramp-down:* All the end-products without any future forecast later than the last month under analysis (so > 2007-M6) and all products for which the average requested sales quantity in period 1 is at least twice as high as the average requested sales quantity in period 3
- *Ramp-up:* Products for which the average requested sales quantity in period 3 is at least twice as high as the average requested sales quantity in period 1.
- *Mature:* All the products not marked as a ramp-up or ramp-down product.

[11] *Sample period is M1-2005 till M6-2007 and is divided in three periods: 1) M01-2005 till M10-2005, 2) M11-2005 till M08-2006, 3) M08 2006 till M06-2007. Periods of 10 months are taken in order to make the comparisons undependable from business cycles (Silver et al., 1998).*

Taking a factor two between the average sales of period 1 and 3 is based on the planner's intelligence and represent a significant decrease or increase in average sales. Whether this factor is slightly more or less than two makes hardly any sense when looking at the deviation of products over the buckets for MAG R-72 (Figure 7.9).

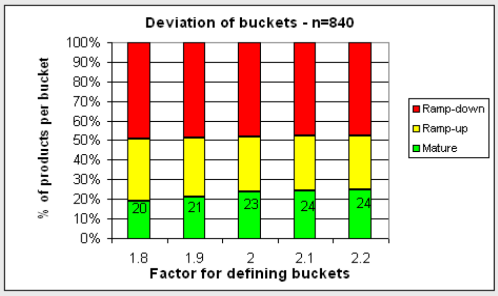
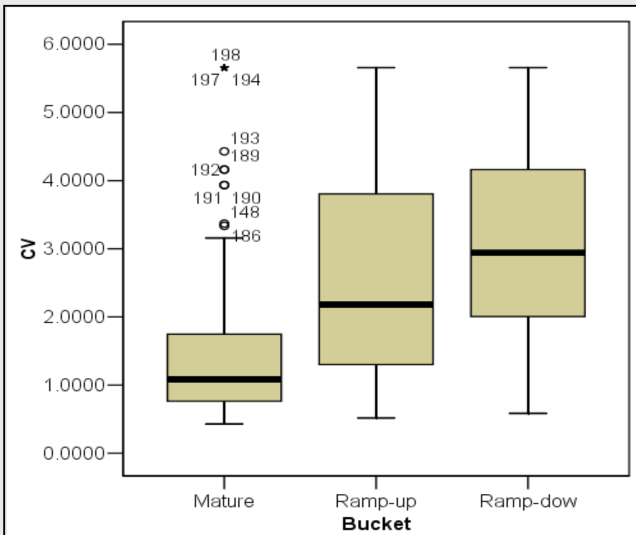


Figure 7.9: Impact of taking another factor than 2 by determining whether a product is mature or

The result of this first sort can best be analyzed by generating box plots (Figure 7.10). A box plot provides information about the deviation of the variables providing information about the 25th, 50th and 75th percentiles of the data under analysis (Huizingh, 2006). To proof that the three buckets are samples from different deviations, the Wilcoxon Signed Ranks test will be used to compare the median (50th percentile) values of the samples instead of the averages. This is a non-parametric test because the deviations do not have a normal distribution and hence the Sample t-test cannot be used (Huizingh, 2006). From each bucket we randomly draw a sample of 70 CVs/observations. The hypothesis we test is as follows:

H_0: There is no difference in the median between the different buckets

H_1: There is a difference in the median between the different buckets



General observations:

- The interquartile ranges (25%-75%) are not the same for all buckets. For ramp-up/down the dispersal is higher.
- The median (50% percentiles) differs per bucket, indicating that we probably deal with three different sample deviations. Significance must be proved.
- The scores in all buckets are positevely skewed indicating that the deviations are not normal distributed.
- Ramp-up en Ramp-down almost have an equal minimum and maximum.
- Only the mature bucket has several upper outliers (>1,5x box-lengte of the 75th percentile) and three extremes (>3x box-lengte of the 75th percentile).

Figure 7.10: Box plots related to sort 1: Sort the end-products based on their life cycle phase.

This hypothesis is test for all bucket combinations and each combination is tested twice (draw different random samples) to be sure of the results given. The test statistics are depicted in Figure 7.11 and hence we conclude that the H_0 hypothesis is not accepted for all possible bucket combinations ($p<0.05$). Hence, sort 2 is a valid sort.

The fact that the difference between the ramp-up/ramp-down bucket is not strong will not be problematic. This is because during the ramp-down phase, no safety stock settings are needed because of the risk of obsolescence. During the ramp-up phase, safety stocks are set on a strategic level based on the trade-off between avoiding risks or being pro-active to the market. Sort 3 will therefore only apply on the mature phased bucket.

	Ramp_down - Mature	Ramp_down2 - Mature2	Ramp_up - Mature	Ramp_up2 - Mature2	Ramp_up - Ramp_down	Ramp_up2 - Ramp_down2
Z	-5,884(a)	-6,399(a)	-4,755(a)	-5,352(a)	-2,040(b)	-2,003(b)
Asymp. Sig. (2-tailed)	,000	,000	,000	,000	,041	,045

a Based on negative ranks.
b Based on positive ranks.
c Wilcoxon Signed Ranks Test

Figure 7.11: Proof of significance sort 2 (Wilcoxon Signed Ranks)

Sort 3

Within the mature bucket the CV can be further specified by sorting the products on their continuity of demand through time (i.e. discontinuous vs. continuous demand). Discontinuous demand (or lumpy demand) generally has a demand pattern that is characterized by periods with a high demand interrupted by periods with zero demand, as opposed to a continuous (or steady) that can be seen as a daily demand (Silver *et al.,* 1998). To define whether a mature product has a continuous or discontinuous demand pattern, the number of months having a zero demand are counted within our historical sales sample. This number shows a strong correlation (R^2=0.86) in relation to the perceived CV and based on that this seems a relevant sort (Figure 7.12). After discussion with the planners we will use the following definition:

- Discontinuous demand: All mature products for which the number of months with a zero demand (out of 30) is within the interval [10..30].
- Continuous demand: All mature products for which the number of months with a zero demand (out of 30) is within the interval [0..9].

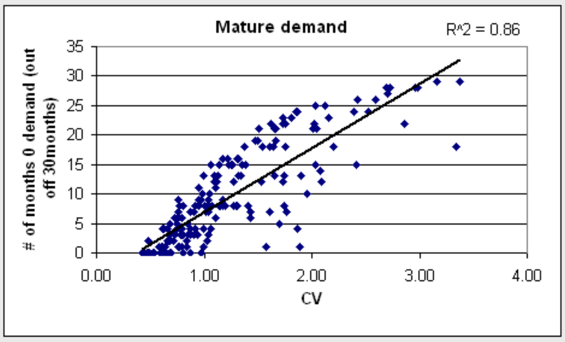


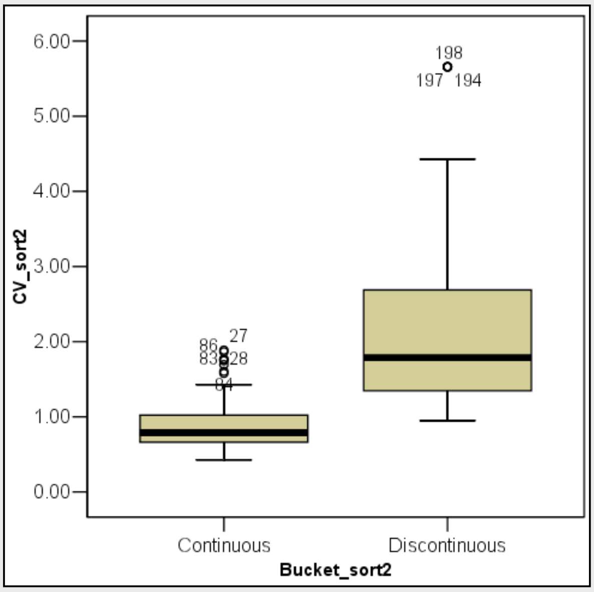
Figure 7.12: For mature products, a strong correlation (0.86) can be found between the perceived CV and the number of months with zero demand.

The box plot of both samples is showed in Figure 7.13 and to proof that these two buckets are samples from different deviations, the Wilcoxon Signed Ranks test will be used to compare the medians. Again, we randomly draw a sample of 70 CVs per bucket and the hypothesis we test is as follows:

H_0: There is no difference in the median between the continuous and discontinuous bucket

H_1: There is a difference in the median between the continuous and discontinuous bucket

This hypothesis is tested twice (different random samples) to be sure of the results given. The test statistics are depicted in Figure 7.13 and we can conclude that the H_0 hypothesis is not accepted ($p<0.05$) for both performed tests. Hence, sort 3 is a valid sort.



	Discontinuous - Continuous	Discontinuous2 - Continuous2
Z	-7,002(a)	-6,868(a)
Asymp. Sig. (2-tailed)	,000	,000

a Based on negative ranks.
b Wilcoxon Signed Ranks Test

Figure 7.13: Box plot and the proof of significance of sort 3 (Wilcoxon Signed Ranks)

Other sort options available?

During above analysis two other sort options were considered but both options were rejected after further analysis, namely:

1. *Sort the CV based on the percentage of sales generated by the number one customer*: The general assumption is that the fluctuations in demand will be relatively higher for products with less customers in their customer base (Silver *et al.,* 1998). Analyzing the relation between 'the percentage of the number one customer' and the CV per continuous or discontinuous demand bucket shows us a correlation factor of respectively 0.11 and 0.09 and hence a further distinction of the products that are labeled as continuous or discontinuous makes no sense. The correlation factor is 0.39 for the relation between 'the percentage of the number one customer' and the CV of the products within the mature bucket (so continuous and discontinuous together) and based on this we also see no reason to sort the products based on the number one customer share in an earlier stage.
2. *Sort the products based on an ABC classification (Pareto curve):* The idea is to use this classification in combination with the assumption that the high runner/volume products (A-items), in general have a lower CV than the slow movers low volume products (C-items) (Silver *et al.,* 1998). According to the planners, this is not advisable because they indicate that a part of their mature products can be labeled as stable/predictable (low CV) despite it is a low volume or slow mover product. This statement is proved via an analysis of which the results are depicted in Figure 7.14 in combination with the conclusion that mature products have a lower CV than non-

mature products (cf. sort 2). Comparing the upper left and lower left graph, we can conclude that the high runners are not only the mature products (lower left graph). When sorting the products based on an ascending CV, we see that the mature products generally have a lower CV (lower right graph, and already proved under sort 2). Using this sorting method will provide us another curve related to the sales generated (upper right graph). Hence a sorting based on the generated percentage of total sales to determine the CV is unadvisable.

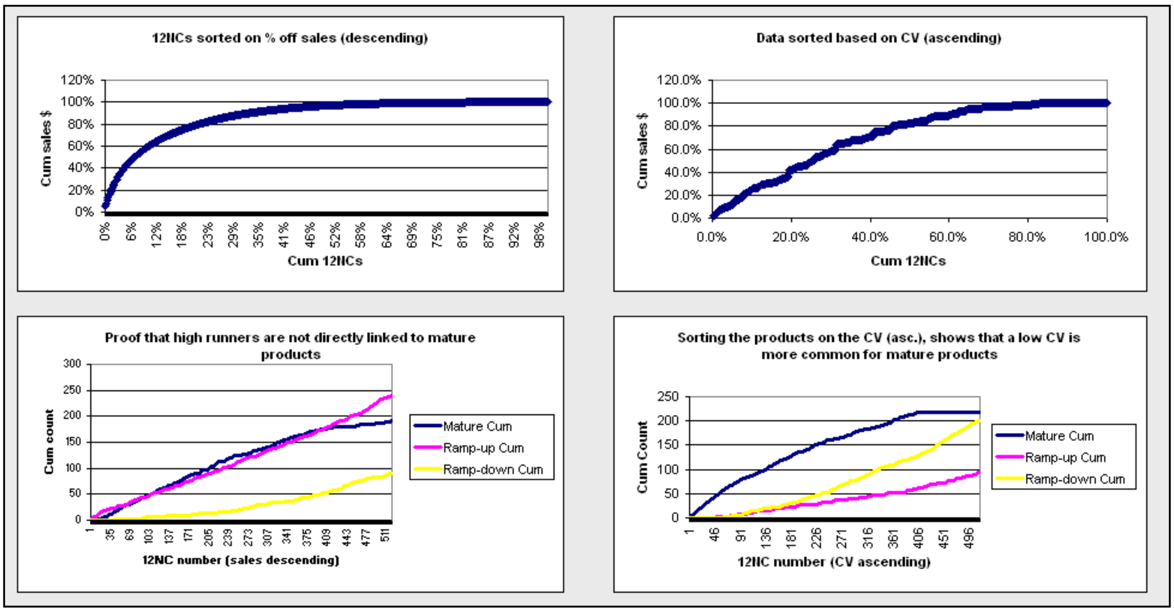


Figure 7.14: Proof that not all high runners should not all have a relative low CV

Result

Using the sorting method as outlined in this section will give us the results as depicted in Figure 7.15 (see Appendix J for details). The calculated median is stable when using different samples (<10% difference between median sample 1 and 2). The median per bucket is used resulting in the fact that some products within this bucket will be overestimated and some products will be under estimated with respect to the needed safety stock level. This will not be a problem because:

- The underestimation will mainly occur for products with an exception (e.g. a peak demand x times higher than the average demand) which leads to a higher CV. An underestimation of the safety stock in these cases will not be a problem because the planners are solving those peaks via manual interventions like pre-builds.
- An overestimation will mainly occur for the rest of the products. But as can be seen in the Pareto curve these products are more likely class A items and hence the risk of obsolescence will decrease. From a market view it means that you will provide a higher service to these class A items.

Results Experimental situation III			CV to use
R72	Mature demand		-
		Continuous Demand	0.79
		Discontinuous Demand	1.80
R73	Mature demand		
		Continuous Demand	0.65
		Discontinuous Demand	1.62
	Ramp-up		
		SCOpE can be used but SS placement within this phase is more strategic (risk avoidance vs. pro-activeness).	
	Ramp-down		
		SS are highly un-advisable because of obsolescence risk	

Figure 7.15: Bucket CV to used for R72 and R73 within MMS-PM

7.4 Effect of improvements made

Compared to chapter 5, several improvements were made that will probably increase the validity of SCOpE as determined in chapter 6. An overview of the improvements made can be given as follows:

Improvement area	Before improvement (chapter 5)	After improvement (chapter 7)
Yield fluctuations	Incorporated by Ton de Kok separately. No details available.	
Batching (sec. 7.1)	Not incorporated in SCOpE	Incorporate by increasing the review period for situations in which the demand during a review period is less than the batch size.
Average demand (sec.7.2)	The average system forecast over the next 13 weeks is calculated per end-product.	The average business line forecast over 13 weeks is calculated starting 4 weeks from now and per end-product.
Standard deviation (sec.7.3)	The fluctuations of the forecast through time are calculated.	Based on product/market characteristics a representative CV (stand.dev. divided by the average demand) for an aggregated group of end-products will be used and linked to the business line forecast of a specific end-product to determine its standard deviation.

Whether these improvements make sense and thus will decrease the perceived delta between the modeled and the actual situation, the same case studies as performed in chapter 6 will be evaluated again for the same month May 2007. The only difference is that we now incorporate the improvements made within this chapter. The process and the average results[12] per case study are depicted in Figure 7.16. The results are as follows:

- Overall we can conclude that the delta between the service level in the modeled and the actual situation decreases. Hence the improvements made are effective.

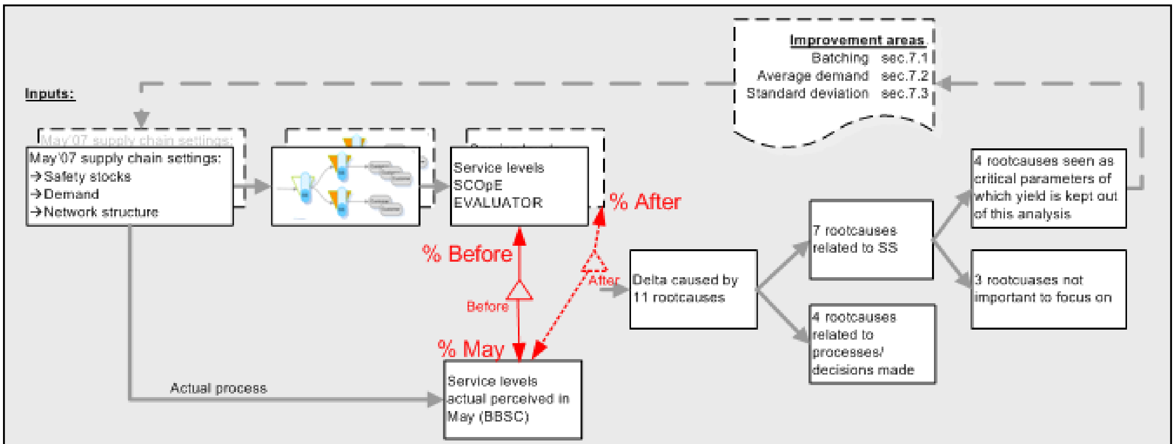
[12] *Using the average service levels per case study is valid because also the RLIP percentage within NXP is measured on 12NC level and no differentiation is made between different customers/CODP locations.*

- As can be seen, the delta will not decrease to zero because the other root causes already mentioned in Chapter 6 remains unchanged.

Related to this process the following critical note can be made:

- Although we conclude that the three improvements made are effective, this conclusion is only based on the average results of the five case studies performed for a single moment in time (May'07). Therefore exceptions within a specific case can lead to accepting or rejecting the improvements made.

To deal with this drawback, accepting or rejecting the improvements should be done over a longer period of time. This can be done by setting up a pilot project (or a simulation study) within NXP in order to find out whether the optimized safety stock settings indeed will lead to an overall better service level. The already chosen case studies can be used for the pilot and after optimizing the safety stocks over the network and implementing these settings in practice, the service levels must be analyzed during the coming months.



Case		RLIP as is (May'07)	RLIP evaluator - Before	RLIP evaluator - After	Impact on perceived delta	
Case 1	331372128301	95%	65%	70%	↓	Because of the improved parameters, the model becomes a better represenation of the actual situation
Case 2	331373484301	82%	88%	83%	↓	Because of the improved parameters, the model becomes a better represenation of the actual situation
Case 3	331371914301	90%	100%	100%	=	Because of the extremely high safety stocks, better or worser parameter settings are not visual anymore
Case 4	331372326301	77%	82%	81%	↓	Because of the improved parameters, the model becomes a better represenation of the actual situation
Case 5	331373118301	64%	55%	56%	↓	Because of the improved parameters, the model becomes a better represenation of the actual situation

Figure 7.16: Process to find whether the improvements made are making sense and the average results of the case studies respectively performed before and after the improvements made.

7.5 Conclusion

In this chapter we improved the way to capture critical parameters as indicated during the model testing phase in chapter 6 and forms the last phase of research question 2. The improvements made in order to increase the validity of SCOpE are as follows:

Improvement area	Before improvement (chapter 5)	After improvement (chapter 7)
Yield fluctuations	Incorporated by Ton de Kok separately. No details available.	
Batching (sec. 7.1)	Not incorporated in SCOpE	Incorporate batching by increasing the review period for situations in which the demand during a review period is less than the batch size. When the demand during a review period is taller than the batch size, no excess stock will occur because then MOQ+k*RQ will lead to a batch size that equals the demand (because MOQ>>RQ).
Average demand (sec.7.2)	The average system forecast over the next 13 weeks is calculated per end-product.	The average is calculated based on the business line forecast because this is the best information available of the future demand at a certain time. The average is calculated over 13 weeks starting 4 weeks from now and per end-product.
Standard deviation (sec.7.3)	The fluctuations of the forecast through time are calculated.	Based on product/market characteristics a representative CV (stand.dev. divided by the average demand) for an aggregated group of end-products will be used and linked to the business line forecast of a specific end-product to determine its standard deviation. Aggregation is used to overcome the limited data availability within NXP and the highly unstable forecast accuracy.

After extension of SCOpE with these improvements made, the SCOpE results were evaluated again for to the same case studies in the month May 2007 (cf Chapter 6). For all cases the model improved by introducing these parameters in the sense that the delta between the actual and the modeled service level decreases. All the introduced parameters make the model more similar to the real supply chain practice.

The limited amount of cases evaluated and the short review period considered (May 2007) give too less data to prove this finding fully. To have this prove, optimized inventory levels should be implemented in practice after which service levels must be analyzed during the coming months. This will also provide us further insights in the real benefits of using a supply chain optimizer like SCOpE within NXP.

Chapter 8 Using SCOpE in practice

Now we defined the way to capture the average demand, standard deviation and batching parameters, we can apply the model to our chosen case studies in order to answer the third research question. This will be done by using the optimization mode of SCOpE for the same case studies as used during validation (chapter 5 till 7). This is not only the basis for a pilot project to find out whether SCOpE leads to better and more stable service levels over a longer time span but will also provide further insights in the real benefits of SCOpE while using the optimization mode. This chapter will start by providing an overview of the case study results by using the optimization mode for the month June 2007 (section 8.1) followed by the way we implemented these results in practice (section 8.2). In section 8.3 we will elaborate on the application areas and the impact of using SCOpE within MMS-PM and within NXP. We will close this chapter with a conclusion in chapter 8.4.

8.1 Case study results after optimization

In Figure 8.1 the results of case study no. 1 are depicted after we used the optimization mode of SCOpE for the month June 2007. The upper part shows the graphical representation of the supply chain (see Appendix H or Chapter 6 for an explanation of how to read supply chain with respect to the products, customers and different CODPs). The current (as is) situation and the desired/optimized (to be) situations per stock location are given with respectively the actual safety stock targets (red bars) and the optimized safety stock targets (green bars). The proposals for this case are:

- Reduce the safety stock settings at the die bank (#3) from 4 weeks to 1 week.
- Increase the safety stock settings at the Philips-CP (#6) from 0 to 1 week (12NC: 934055896127)
- Increase the safety stock settings at the IWH (#7) from 0 to 1 week (12NC: 934055896127).

By doing this, we expect that the service level will increase to 79%. Using the current safety stock settings (red bars) as input show that these settings will only lead to a service level of 62% while the safety stock costs are higher. Thus by a better division of the safety stocks over the network the service level will increase from 62% to 79% and the safety stock costs will decrease by 20%. In practice, we expect a higher service level than 62% because of the high projected inventory levels through the supply chain as already indicated during the root cause analysis in chapter 6.

In the lower part of Figure 8.1 two graphs are depicted with the conclusions that a 20% reduction in the average safety stock costs can be achieved, a 80% reduction in the average inventory levels could be achieved (based on the projected inventory levels expected in June) and that the service level can be increased from 62% to 79%.

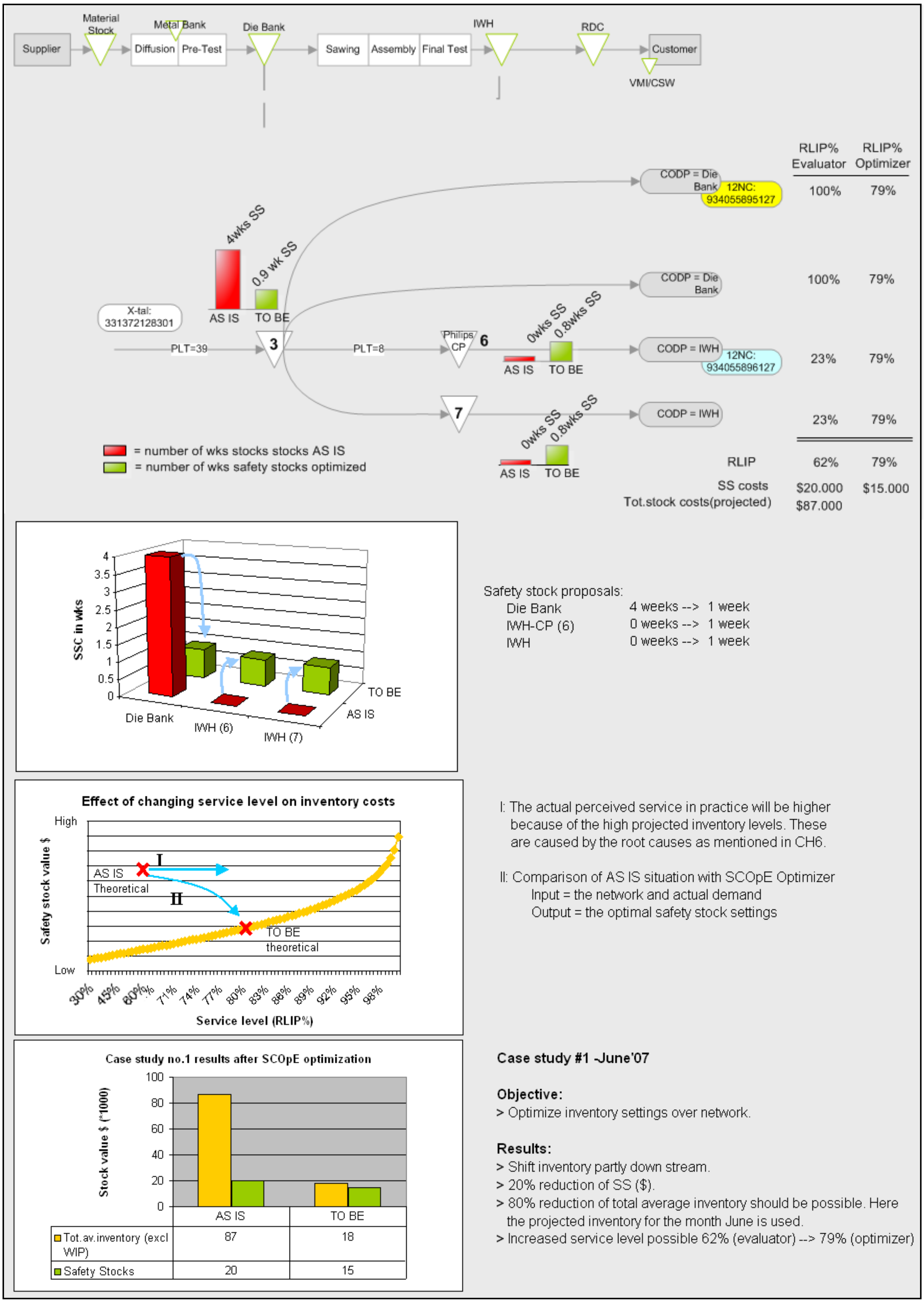


Figure 8.1: Overview of the results of case study no.1 optimized in June 2007 (the other cases are plotted in Appendix I)

The results of the other case studies are depicted in Figure 8.2. The safety stock reduction percentage is based on the average safety stock levels in June 2007. The inventory reduction percentage is based on the projected inventory during June 2007. The high percentages indicate that the current inventory levels are extremely high for these case studies which is caused by utilization, over-forecast or a too high planned lead time (i.e. 90% percentile). The service levels are respectively the service level as calculated by the evaluator and optimizer mode. Related to case 2 and 3, the service levels will decrease because we optimize against a predefined target of 79%. The details of the cases 2 till 5 (similar to Figure 8.1) are depicted in Appendix K.

Case	$ SS reduction (%)	$ Inv.reduction (%)	Service level
1	20%	80%	62% -> 79%
2	60%	65%	86% -> 79%
3	75%	75%	100% -> 79%
4	65%	80%	79% -> 79%
5	No, 0wk to 1wk	90%	31% -> 79%

Figure 8.2: Overview of the results the case studies performed (for details see Appendix I).

8.2 From proposal to implementation

To find out whether the optimized safety stock settings as defined in the previous section will indeed improve the service levels over a longer time span (cf. section 7.4), the proposed safety stock settings will be implemented in practice starting at September 2007 after which monitoring per case study can be started.

The proposed safety stock settings as outlined in section 8.1 (appendix K) are the result of the month June 2007 and we found that the dynamic safety stock coverage settings (rounded to an integer not smaller than the optimum) were stable through the months May, June and July 2007. Hence we are able to use these settings in practice in the month September 2007. Although, two major changes were made:

1. At the beginning of September 2007 all R72 safety stocks were reduced to zero weeks in order to fulfill the high management pressure to reduce stocks. Of course, it is very unwise to do so because as already indicated, the high inventory levels are not mainly caused by safety stock settings and besides that, safety stock is needed to guarantee the predefined service levels.
2. Case 1 has introduced an extra Philips-CP at the IWH for the end-product 934055896127.
3. Case 5 is split up in two different dies.

Hence, case study no.1 and no.5 are calculated through again. The proposed settings per case study, the actions we took and the discussions that were triggered are summarized in Figure 8.3.

Case	CODP	Proposed	Action	Next
1	Die bank	0wk -> 1wk	Agreed	Monitoring
	IWH	0wk -> 1wk	Shift CODP downstream?	Analysis
	Philips-CP	0wk -> 1wk	Agreed	Monitoring
	Philips-CP	0wk -> 1wk	Agreed	Monitoring
2	Die bank	2.5wk -> 1 wk	Not agreed because of allocation for SOT23	
	Ford CSW	Actual = proposed	No action needed	
	Multiple CPs	Actual = proposed	No action needed	
3	Die bank	1wk -> 1wk	No action needed	Monitoring
	Siemens CSW	2wk -> 1.8wk	No action needed	Monitoring
	Bosch CP	2wk -> 1wk	Not agreed because of Bosch CP	Monitoring
4	Die bank	0wk -> 2wk	Agreed	Monitoring
	IWH CP	0wk -> 1wk	Agreed	Monitoring
5a	Die bank	4wk -> 2 wk	Not agreed because of marketing actions	Monitoring
5b	Die bank	0wk -> 2 wk	Not agreed because of risk involved (single customer -Risks involved (few customers) -Die is the same as 5a, but other BE factory	Monitoring

Figure 8.3: Overview of the proposed settings, the actions we took and the next step to take

The main observations per case are as follows (cf. Figure 8.3):

Case no. 1
- A discussion is triggered with respect to the correctness of the current CODP settings. SCOpE proposed that there should be a safety stock setting of 1 week at the IWH in order to meet the order lead time of these customers (CODP=IWH). Although, the planning manager is reluctant to do so because of the costs and risks (flexibility/obsolescence) involved. Because of that, a CODP analysis will be performed based on the order behavior of these customers and the importance of these customers for the BL.
- The other proposals were agreed mainly because of the CPs.

Case no. 2
- Because this case is in an allocation we did not reduced the safety stock settings. On the other hand, safety stock setting will not make any sense because all capacity will be used to fulfill orders instead of building up safety stocks.

Case no. 3
- The current safety stocks are in line with the optimized settings.
- The safety stock of the Bosch CP cannot be simply reduced because a service level agreement states the number of weeks that should be covered instead of the service level that should be achieved. Besides that, Bosch is a NXP key customer and hence some extra safety is a plus.

Case no. 4
- All proposals were agreed and implemented.

Case no. 5a/b
- These products have virtually the same die but are produced in different front-end factories. Products related to case study 5a are high volume, high runner products. Products related to case study 5b are low runners. Therefore the proposed settings were rejected because the risks of placing safety stock for case study 5b is high; the die stocks between case study 5a and 5b are interchangeable; and the marketing expects high sales and hence uses safety stock settings as anticipating stock.
- I did not completely agree on the rejected settings for case study 5b because

the risks of obsolescence is not that high because excess stock can be transported to the die bank of case study 5a. I suggested to closely monitor both cases to get evidence of the correctness of the proposed optimized settings.

During the months September, October and November 2007 the planners need to monitor whether the proposed safety stock settings are indeed leading to better service levels related to our implemented case studies. When the service levels will not improve, planners need to perform a root cause analysis to find out whether a RLIP miss is caused by incorrect safety stock settings. Based on that analysis, proper actions can be taken to increase the RLIP and a final decision can be made whether SCOpE will improve the service levels over a longer time span. This process is in line with the common used plan-do-check-act (PDCA) cycle and is depicted in Figure 8.4. Because of time restrictions the check and the act phase are not finished yet.

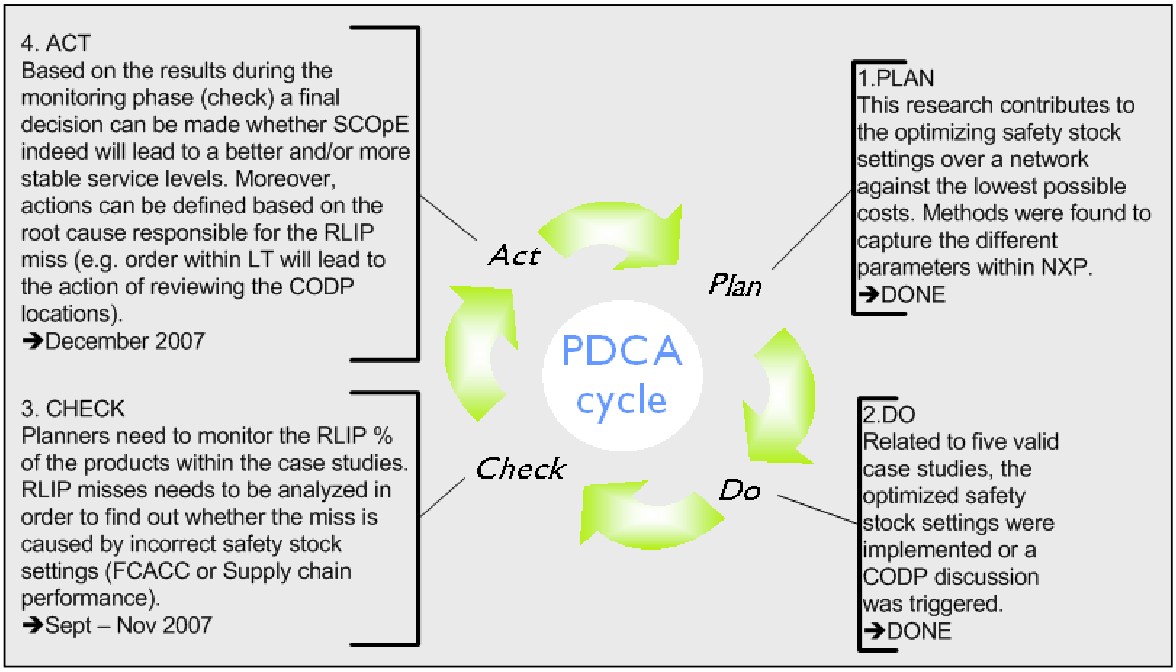


Figure 8.4: Monitoring needs to be done by the planners to find out whether the improved safety stock settings indeed will lead to better and more stable service levels. This steps is an element of the check phase within the PDCA cycle commonly used within NXP.

8.3 Application areas of SCOpE and impact within MMS-PM

Whether SCOpE is applicable in practice depends on the life cycle phase of the individual products.

- *New product introduction (NPI) and volume ramp-up (VRU) phase*: Within this phase, SCOpE should not be used because the following two reasons. First, because of the highly fluctuating product/market characteristics it is not trivial to use mathematical optimization models. This is caused by an extremely high CV (cf. section 7.3.3), highly fluctuating production parameters and a high probability to have an under-FC (dynamic safety stocks will have no sense at all).

Secondly, placing safety stock for a ramp-up phased product is more a strategic BL decision with respect to the decision whether to take risks in combination with whether to be pro-active to the market. Further analysis is needed to define a policy how to deal with these situations.

- *Mature phase*: SCOpE can be applied very well within this phase because the product/market characteristics are more stable and it is less risky to place safety stocks because of the possibilities of future sales. All mature products can be calculated through because SCOpE is able to deal with batching, multi-die, multi-source (when percentage of spit is known), yield fluctuations[13], lead times[14], multi- and single customers, customer programs (CPs) and over- and under-forecasts[15].
- *Ramp-down phase*: Using the model for products within this phase is also not advisable. Generally speaking the safety stock settings should be zero because of the risk of obsolescence. Although, it depends on the strategic intent of NXP.

A main assumption while using SCOpE is that the CODP locations are known beforehand and that customers are aware of this location while placing their orders (cf. root cause no.2 and 9). This implies that SCOpE is not a stand-alone tool but should interact with the current available SCC tool and the Zero Based Inventory Budgeting tool (ZBIB). The proposed process to follow is depicted in Figure 8.6. and can be explained as follows:

Level?	What?	How?	Who?	When?
Strategic	1) Define key customers, key battles, order LT, inventory budgets and service levels targets	A strategic statement will be given related to how NXP wants to profile itself in the market to specific customers. These statements are the boundaries for the lower levels and the ZBIB tool can help to define the budgets.	BU management & Global SCM	Yearly
Tactical	2) Review CODP locations and make trade-off between service and inventory budget. 3) Optimize safety stock settings.	Given the budgets and targets defined at the strategic level, the BL should make a trade-off between the CODP location (order LT to give) and the corresponding inventory investments needed. The SCC tool will help to assess whether the strategic defined order LT to specific customers is in line with their actual behaviour. SCOpE can give insights in the consequences of the choices with respect to the investments in safety stock needed. When this will exceed the budget given, step 2 must be performed again (scenario analysis). When the CODP location with the corresponding inventory investments are in line with the budget given,	Supply chain managers and OFCs planning managers	Quarterly/ Monthly

[13] The yield itself can be solved within the planning engine. It are the yield fluctuations that are important for the safety stock settings.
[14] Lead times will be incorporated by using planned lead times (90% percentiles). Other supply problems will be incorporated by making the distinction between normal and effective planned lead times within the model.
[15] The model can be used despite the FCACC. Although, it is generally known that the better the FCACC, the lower the safety stock settings because in that case the average BL FC equals the average actual sales.

		the settings can be implemented at the operational level.		
Operational	4) Implement & monitor the performance	At the operational level, the CODP and safety stock settings can be implemented. Important is to monitor the performance via two out-of-control measurements (cf. the PDCA cycle depicted in Figure 8.4). The first indicator should be the service level. When below or far above target, a root cause analysis need to be done and when the mismatch can be linked to wrong CODP or safety stock settings, an assessment at the tactical level needs to be performed again. A second indicator should be the inventory percentage (this percentage is only measured at BL level). When this percentage is above target, budgets should be assessed or CODP locations should be changed if possible. This step should be performed by the responsible planners.	Planners within OFCs	Monthly/ Weekly

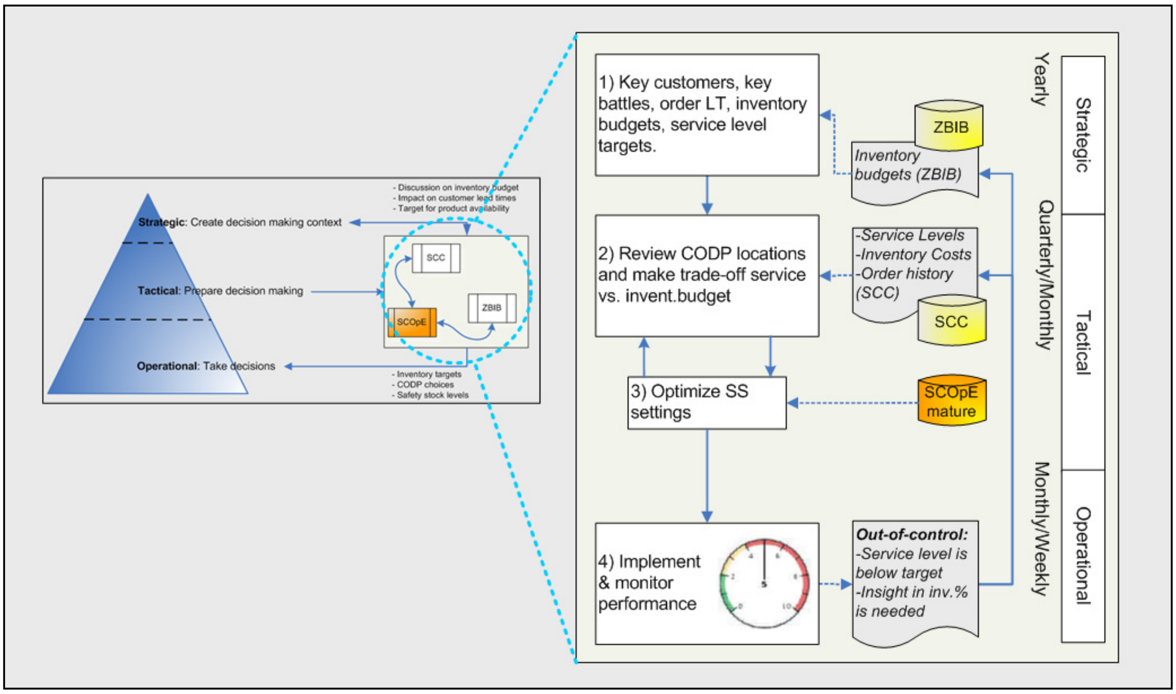


Figure 8.6: SCOpE should be placed at the tactical level and should be used in combination with the SCC and ZBIB tool.

Within MMS-PM, above outlined application areas implies that (Figure 8.5):

- SCOpE can be used for approximately 70% of the end-products representing approximately 90% of total MMS-PM sales (à $193M).
- 55% of the total safety stocks are related to the mature phased products and thus represent $2.2M of the total safety stock value. But these 55% of safety stocks are only caused by 36% of the mature end-products because 64% of the mature MMS-PM end-products do not have any safety stock settings at all.

Based on these observations we can conclude that despite SCOpE is applicable to the main part of the MMS-PM business, cost reductions are not trivial. Besides that, safety stocks are representing only 10% of the total stock available (excluding WIP). Therefore, SCOpE should not primary used to obtain inventory reduction but SCOpE should be used in order to make a rational trade-off between costs and the perceived service levels.

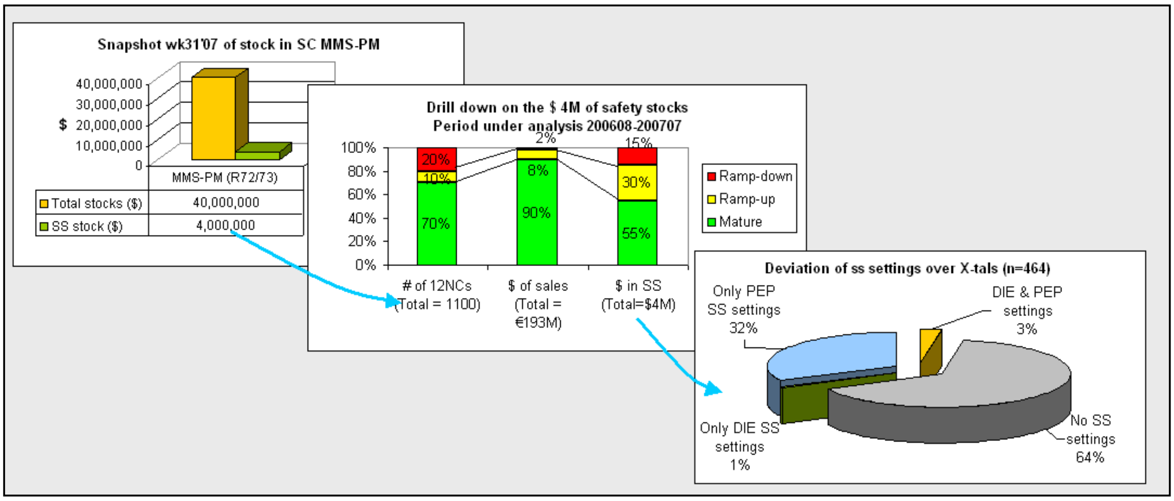


Figure 8.5: Facts and figures within MMS-PM related to safety stock deviations over the mature products within MMS-PM.

8.4 Conclusion

Research question three deals about what the benefits, limitations and application areas are when applying SCOpE in practice.

Related to the benefits and limitations we can conclude that:

- SCOpE optimizes inventory levels which leads to a better division of safety stocks over the network such the targeted service levels can be reached against minimum costs.
- Whether targeted service levels indeed can be reached in practice over a longer time span, the selected case studies must be monitored during the months September, October and November.

- SCOpE supports the continuous learning process of the planners when rationalizing the supply chain settings. More specific:
  - SCOpE evaluates the consequences of given CODP locations. Hence planners are triggered to think whether they really want to provide the current order lead time to this group of customers given the safety stocks cost involved.
  - SCOpE can be used to perform a sensitivity analysis with respect to the effect of the input parameters on the perceived service or optimal safety stock settings.
  - SCOpE is able to support the decision making process with respect to CP safety stock placements and with respect to marketing pressure of placing safety stocks. Irrational settings can be avoided.
  - SCOpE will visualize available inefficiencies within the supply chain with respect to increased utilization, over-FC, and pre-builds.

Related to the application areas we can conclude that:

- SCOpE is applicable for all mature products. During ramp-up or ramp-down using SCOpE will not make sense. During ramp-up, safety stock placements should be the result of a strategic trade-off between market pro-activeness and risk avoidance. During ramp-down, safety stocks are un-advisable because of the obsolescence risks.
- SCOpE is not a stand-alone-tool but should interact with the SCC and ZBIB tool at a tactical level within NXP.
- Within MMS-PM, 64% of the mature end-products do not have safety stock settings at all. Therefore, SCOpE should not be used to reach inventory costs reductions but the focus should be to provide the targeted service levels against minimal supply chain costs.

Chapter 9 Conclusions and recommendations

In this last chapter, the main conclusions and recommendations following from this research are provided in respectively section 9.1 and 9.2.

9.1 Conclusions

Based on the research done, the following conclusions can be made:
- Based on the case studies performed, SCOpE optimization outcomes indicates that there is a sizable potential to reduce safety stocks while maintaining or increasing service levels.
- Monitoring the optimized safety stock settings in the next coming months is necessary to validate the service levels through time. These settings were implemented for the case studies in September 2007.
- SCOpE completes the available tool set around inventory management in NXP, namely the supply chain configuration tool (SCC) and zero based inventory budgeting tool (ZBIB) and can support basic supply chain modeling decisions.
- SCOpE does not support the optimal CODP location, although SCOpE is very well suited to evaluate the consequences of given CODP choices.
- The current SCOpE version is not user-friendly enough for immediate use within a planner environment. The supply chain modeling in SCOpE is complex and data gathering is time consuming.

Besides these main conclusion, several other conclusions can be drawn from this research:
- Safety stock costs are only a minor part of the total inventory levels available within NXP.
- SCOpE calculates optimized safety levels in order to reach the targeted service levels. This does not automatically imply inventory cost reductions.
- Before using models in practice and to draw significant correct answers, one must be sure to have sufficient data. If this is not the case, we found that aggregation can be used to overcome this gap.

9.2 Main recommendations

Based on the research done, five main recommendations can be formulated:
- Monitor the service levels of the pilot projects during the months September, October and November in order to assess whether SCOpE indeed leads to better and more stabilized service levels through time.
- Do not focus on (solve the) three root causes marked as less relevant within the SCOpE logic, namely order cancellations/returns, rounding quantities and P_2 vs RLIP measurement. Effort can better be put in the root causes related to the process and decisions made related to inventory (see next recommendation).

- The high inventory levels within NXP are not caused by incorrect safety stock settings but are mainly caused by an over-forecast, increased utilization or a lower planned lead time than expected. Hence, more focus should be on these three issues in order to reduce inventories.
- Review the CODP locations on a frequent basis. Currently this is hardly done and therefore the CODP settings within the planning system are not in line with the customer behavior. The result is an inefficient supply chain, too high inventory costs and often a lower service level than expected.
- The current SCOpE version, is not user-friendly enough for immediate use within a planner environment. Hence, four different scenarios are identified and we recommend to go from 1 to 4 in the next coming months in order to reap the benefits of the research performed:

  Scenario 1: Use SCOpE and inventory concepts within SCM courses.

  During this research we gained insights in inventory management concepts and in the interaction of parameters related to safety stocks. These insights should be incorporated within the SCM courses of the NXP Academy in order to increase the knowledge of the planners with respect to the effects of inventory on their service levels. Action has been taken.

  Scenario 2: Use SCOpE for the definition of guidelines.

  This step can be performed with minimal effort. Guidelines can be subtracted from this thesis (e.g. when most value is added downstream, most safety stock should be allocated upstream and CODP location must be set to the most possible upstream location in relation to order behavior/strategic intend) in order to develop a decision tree with guidelines which supports decision making related to CODP and safety stock settings. We expect that this step will already improve the current situation because currently the planners do not really know what to do. Action has been taken.

  Scenario 3: Use SCOpE for scenario analysis.

  SCOpE can be used when there is a lack of insight in safety stock settings or when the perceived service levels are not met. Hence, the out of control measures will trigger the usage of SCOpE. We recommend to assign a SCOpE champion per order fulfillment center and to adapt SCOpE by using modular building blocks. Investments are needed and management will decide whether to incorporate this step in the inventory management roadmap of 2008.

  Scenario 4: Incorporate SCOpE in the system environment within the SCM organization.

  This targeted situation is currently not realistic as already concluded in section 9.1. First because SCOpE is not mature enough to interact with the multiple systems available. Second, the interface of SCOpe is too immature to given an answer to planners with respect to safety stock settings in a timely manner (see scenario 3). Therefore, at this moment no action can be taken related to this scenario.

	Scenario's	Remarks	Action to be taken	Target audience	Effort needed
V	1. Use tool within SCM courses	Action is running, insights gained in this project will be used in advanced SCM course. ➔ **Starting from October onwards** (Rob Kuijpers / Jan van Doremalen / Sander Kok).			
V	2. Use SCOpE tool for definition of stock guidelines	Possible, however quality of output is less compared to full network-optimization.	Develop decision tree for to support deciding on CODP / SS settings, link to IM project Jark Snijder ➔ **Starting from September onwards**	Planning managers / planners	Brainstorming & Scenario Analysis SCM CC / Jark / Jan
~/?	3. Use SCOpE tool as scenario analysis tool	Possible, however current SCOpE interface does not support usage in broad community	- Define standard set of supply chains in which only certain variables have to be set -Apply only when assessment is needed to improve service or to reduce SS settings ➔ **Define whether to incorporate this in Inventory Management roadmap 2008**	Planning managers SCM CC	Investigate link ZBIB Develop interface for standard supply chains Data gathering improvements
X	4. Incorporate SCOpE in standard tool set within SCM organization	Not possible, -Multiple sources needed -SCOpE interface too complex	➔ **Not relevant at this moment**	Planners	Not relevant

Figure 9.1: Next steps to be taken with respect to using the benefits of SCOpE in practice.

9.3 Recommendations for further research

During the research performed, we found several other interesting research areas that are kept out of the scope of this thesis:

- Because increased utilization, which is a strategic decision, is a main cause for pre-builds and hence high inventory levels, an interesting research area is to gain insights in the trade-off between wafer-fab utilization and excess stock with the risk of obsolescence.
- Because this research only focused on the mature products, an interesting research area is the strategic trade off made to define safety stocks for ramp-up products.
- We already recommended to review the CODP locations on a frequently basis based on customer behavior or NXP's strategic intent. An interesting research area is how to communicate these settings to the customer, whether the settings are in line with the customer expectations and whether NXP should force customer to behave in line with the settings. When customer behavior and CODP system settings are not in line with each other, a lower service will be reached and/or manual interventions by planners in order to minimize the effects is needed.
- Currently planners are not assessed on the inventory levels they have but only on the service levels they are able to provide. In combination with the fact that high inventory levels generally results in high service levels, planners are not triggered to reduce inventory costs themselves. Therefore an interesting research topic should be to find out whether it is possible to measure the inventory percentage at an end-product level instead of BL level only.
- Ongoing research areas should be the forecast accuracy and the planned lead times because both factors have a high impact on the inventory investments within the supply chain.

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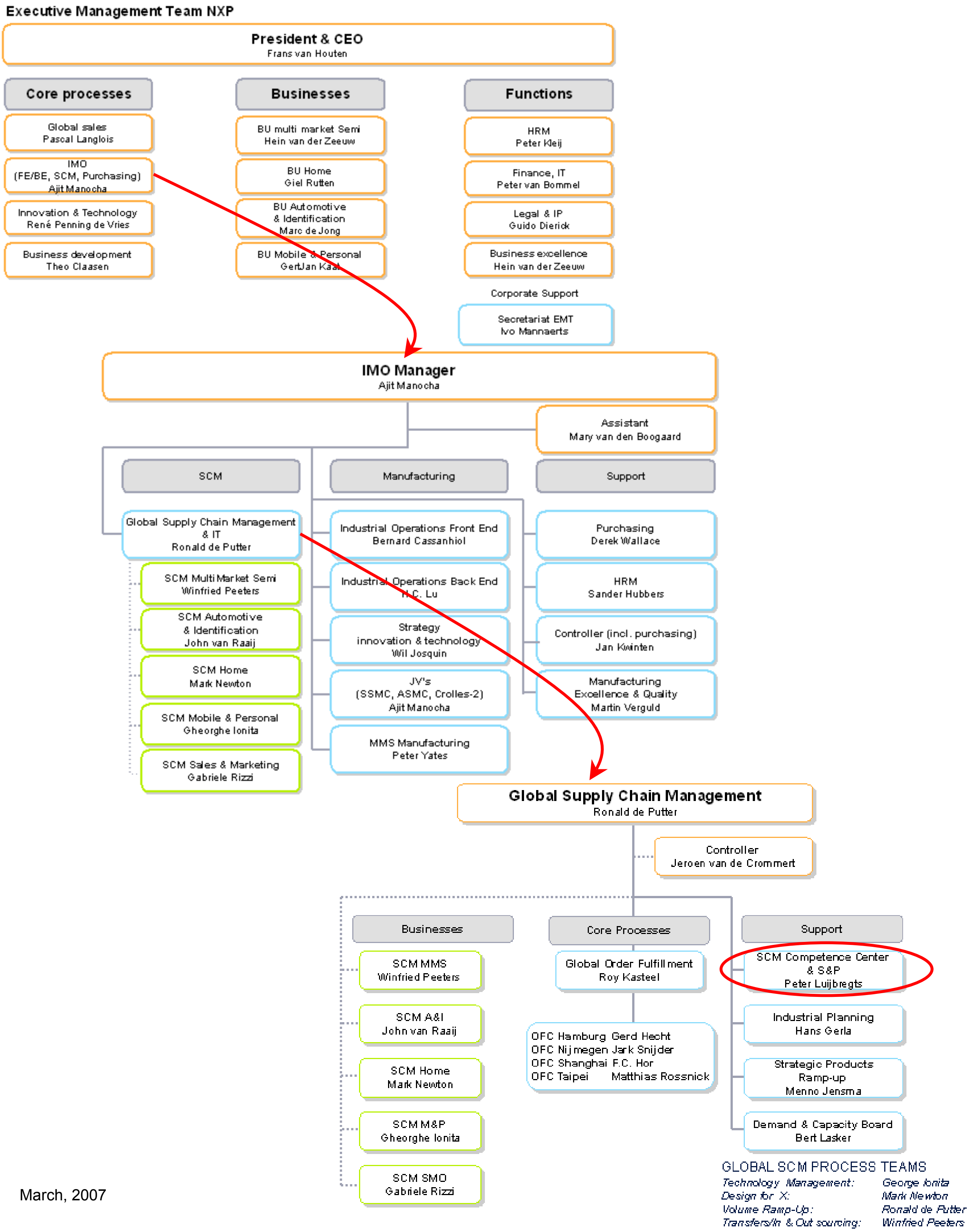
http://nww.nxp.com/imo/scm/, Global Supply Chain Management: Implementation Communication pack, February 2007, last visited in March 2007.

List of Abbreviations

A&I	Automotive & Identification (BU)
BBSC	Business Balanced Scorecard
BLs	Business Lines
BUs	Business Units
CLIP	Confirmed Line Item Performance
CODP	Customer Order Decoupling Point
CSW	Customer Specific Warehouse
CSW	Customer Specific Warehouses
CV	Coefficient of Variation
DBO	Die Based Organization
GSO	Global Sales Organization
IC	Integrated Service
IFO	Interest for Operations
IMO	IC manufacturing Operation
IWH	Industrial Warehouse
IWH	Industrial Warehouse
LAP	Line Acceptance Performance
M&P	Mobile & Personal (BU)
MAG	Main Article Group
MMS	Multi Market Systems (BU)
OFC	Order Fulfillment Center
PM	Power Management (BL)
RDC	Regional Distribution Center
RDC	Regional Distribution Centre
RLIP	Requested Line Item Performance
RLIP	Requested Line Item Performance
SCM CC	Supply Chain Management Competence Center
SCOpE	Supply Chain Optimizer and Evaluator
SG&A	Sales, General & Administration
VMI	Vendor Managed Inventory
ZBIB	Zero Based Inventory Budgeting

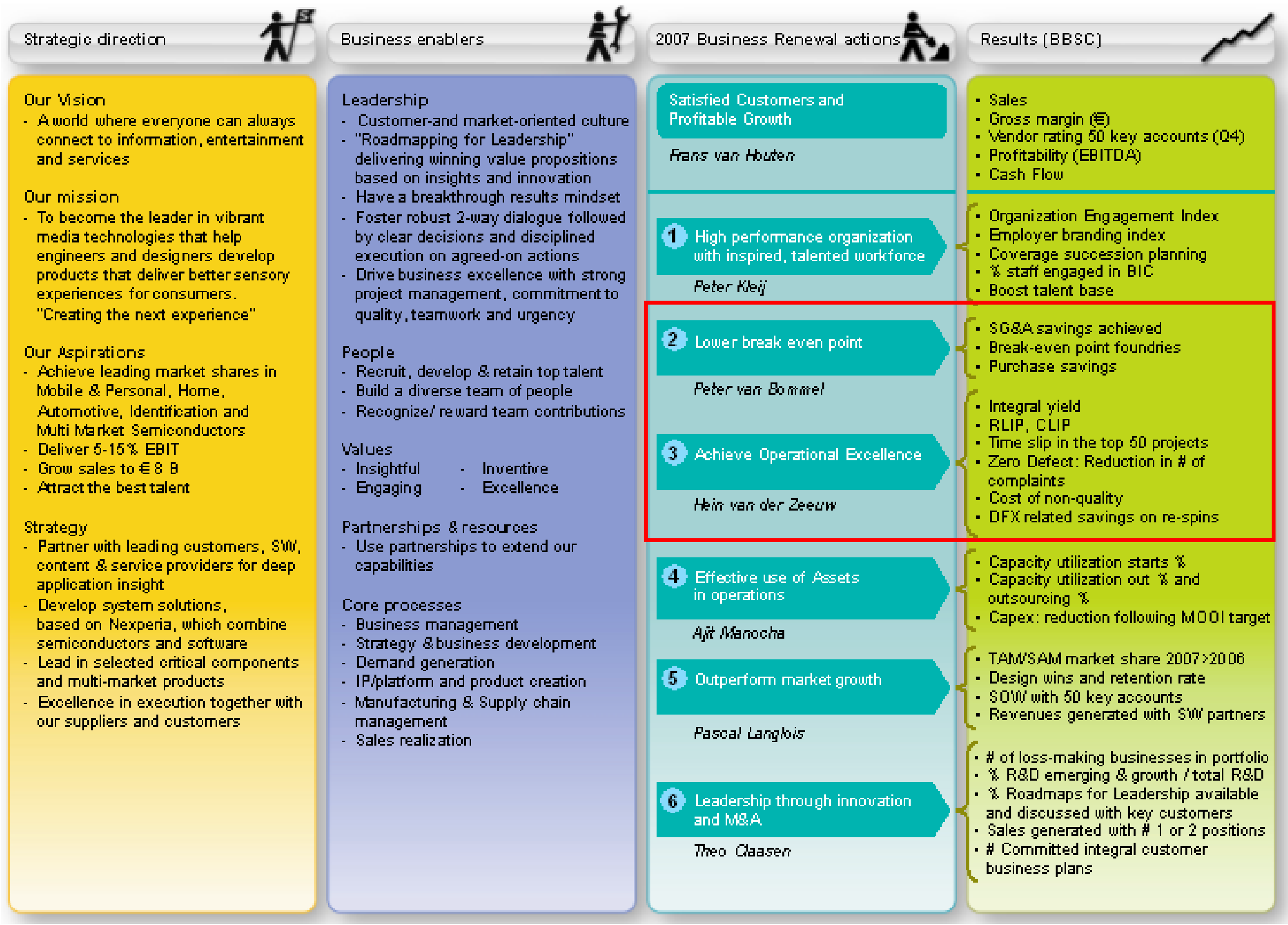
Appendices

Appendix A: Organizational Charts



Appendix B: Business Renewal II actions

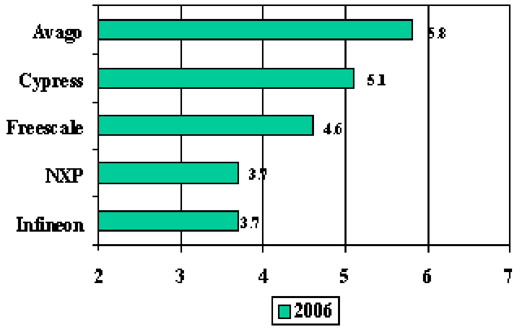
One page strategy 2007



Appendix C: Defining the scope

Period: 2006 Semiconductor business only Confidence index* H

Firm	Rank	2006 Total Turns	Confidence Index
Avago	1	5.8	High
Cypress	2	5.1	High
Freescale	3	4.6	
Infineon	5	3.7	High
NXP	7	3.7	High
Composite		4.2	



Comments

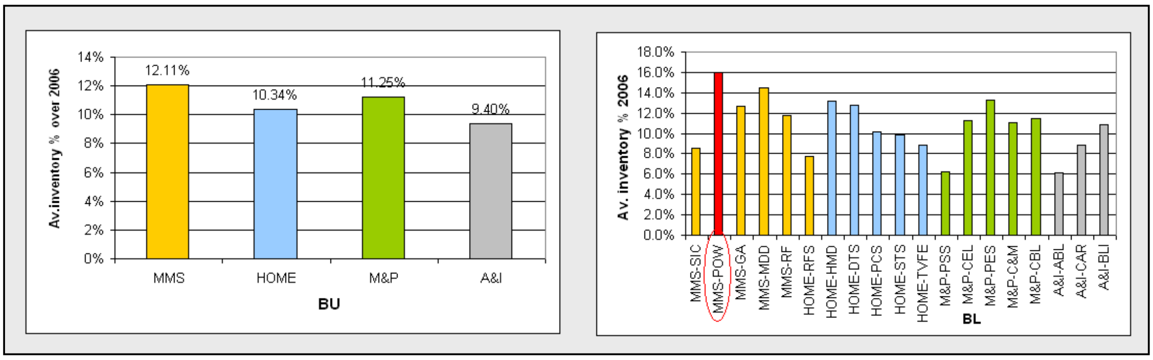
- Confidence Index is based on company self rating
  High -10% ≤ error ≤ +10%
  Medium -20% ≤ error ≤ +20%
  Low |error| > 20%
- And judgmental assessment from ASU and PSU Professors

$$\text{Total Turns} = \frac{(\text{Quarter COGS \$}) * 4}{[(\text{Quarter Beginning FG Inventory \$}) + (\text{Quarter Ending FG Inventory \$})]/2\}}$$

Inventory turns measures the number of times that the capital invested in goods to be sold turns over in a year. Some remarks:

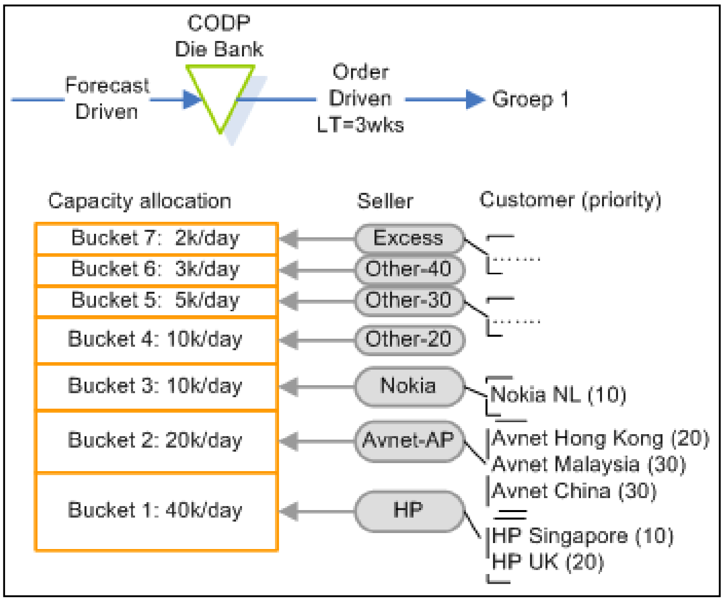
- Use cost-of-goods sold for the numerator based on “standard costs” , not sales.
- The value of inventory should be reported as Gross FG Inventory + WIP Inventory + Raw Materials

NXP uses the inventory percentage, measured as the stock value at the end of the month as percentage of annualized sales of the last three months. For the year 2006, the average inventory percentage per BU (left graph) and per BL (right graph) are depicted. As can be seen, MMS-PM has a 16% inventory percentage which is higher than the rest of the BLs. The target is 12%. The sales split per BU was already depicted in the Figure below from which we can conclude that it makes sense to focus on MMS because they are responsible for 26% of the total NXP revenues.



Appendix D: Shortage policies NXP

In order to give insight in the shortage policies as occur within NXP, the planning process and execution of orders need to be described.



Order entry takes place at the order fulfillment centers (OFCs) located in Nijmegen, Hamburg, Taipei and Shanghai and are passed to the i2six planning engine. In ideal circumstances, this process is carried out automatically, and only in case of exceptions the responsible BL planner will interfere. To give insight in this process, the Figure above shows a simple supply chain with one group of customers who all have the same CODP location. The CODP is located at the die bank and thus the part from CODP to customer dock is order driven which implies that the customers in group 1 are accepting an order lead time of 21 days.

On the lower part of the figure, the capacity allocation per seller (or group of customers) is given which is called a bucket. Suppose a customer (e.g. HP UK with priority code 20) is placing an order at time t with a requested delivery date 21 days from now (i.e. t+21). According to MRP-I logic, the order should be released not later than day t. In order to do so, the engine checks for day t (or for the days before as well when the requested order LT is >21 days) whether there is capacity left (a.k.a. available to promise (ATP)) in bucket 1, at this specific day t. If this is true, the order will be confirmed for day t+21. When there is no ATP left in bucket 1, the engine will look whether there is ATP left at bucket 7, labeled ‘excess capacity’. Allocation of this capacity will be done based on the priority code of the customer (a priority code 10 customer has more change that he will get some ATP from the excess capacity bucket than a priority code 40 customer) and after that based on a first come first serve principle (when multiple customers with the same priority code are asking for extra ATP to release their order). When there is also no ATP left at bucket 7, the engine will check whether there is ATP left at an ‘excess capacity’ bucket which was actually assigned to customers with their CODP more downstream. If this bucket does also not have excess capacity to release orders that will be

finished at day t+21 or before, the order cannot be confirmed at day t+21 and the engine will confirm the order at a latter time stage. In principle, the engine will not automatically use excess capacity from another specific bucket, e.g. use bucket 2 with the ATP for Avnet-AP. In exceptional cases the planner will, but only when he foresees no risks for Avnet-AP in doing this (e.g. when Avnet-AP never uses his allocated capacity because of low actual demand).
When HP UK places an order with a requested delivery date less than 21 days from now, the planning engine will check whether there is ATP left at an 'excess capacity' bucket which was actually assigned to customers with their CODP more downstream. In principle, the engine will never use safety stock for this occasion (e.g. finished goods). This is in line with the theory which states that safety stocks are held to hedge against uncertainties in demand and supply (Van der Heijden & Diks, 1999), and thus not for uncertainties in order behavior because in that case you have to shift your CODP location. However, planners will use this safety stock in exceptional cases, but only when they foresee that there is capacity left to place a SS replenishment order in the short term and when they foresee that the SS will not be used in the short term. Of course this is a very subjective process.

Released production orders at a specific production stage are a combination of confirmed orders (for customers with their CODP before this stage), forecasted orders (for customers with their CODP after this stage) and safety stock replenishment orders. Releasing orders will be done at a weakly basis in the front-end plants and on a daily basis in the back-end plants.

Appendix E: Single location approach

The mathematical expression for a common used single location approach (R,S policy) is as follows:

Order-up-to level (S) = $E[D(R+L)] + k * \sigma[D(R+L)]$

in which $E[D(R+L)] = \mu_D * (L+R)$

$\sigma[D(R+L)] = \sigma_D * \sqrt{L+R}$

with

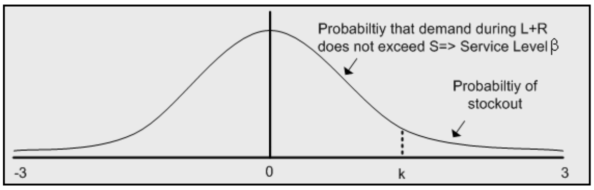
$E[D(R+L)]$	=	expected (or forecast) demand over a review period plus a replenishment lead time, in units
$\sigma[D(R+L)]$	=	standard deviation of errors of forecasts over a review interval plus a replenishment lead time, in units
μ_D	=	average demand in units/time unit
σ_D	=	standard deviation of errors of forecast over a period
S	=	order-up-to level of base stock, in units
R	=	pre-specified review interval, in time units
L	=	replenishment lead time, in time units
k	=	safety factor, see further explanation below
SS	=	safety stock, in units

Assuming a Normal distributed demand during R+L periods which is independent over subsequent periods, the safety factor k can be determined via the following expression (using the no stock-out probability measurement as outlined in section 4.1.3):

Probability {demand over R+L periods $\leq$ order-up-to level (S)} = the probability that the order-up-to level is at least as large as the total demand during a review interval plus lead time.

$$P\{\mu_D(R+L) \leq S\} = k$$

$$\phi\left(\frac{S - \mu_D * (R+L)}{\sigma_D \sqrt{R+L}}\right) = \phi(k)$$



where $\phi(.)$ denotes the standard normal probability distribution function. Hence the actual no stockout probability equals the target value if $\phi(k) = \beta$ and so the safety factor k should be determined from $k = \phi^{-1}(\beta)$. These equations in order to determine the safety factor k will differ when using other performance measurements as outlined in section 4.1.3 (see Van der Heijden & Diks (1999) for more details).

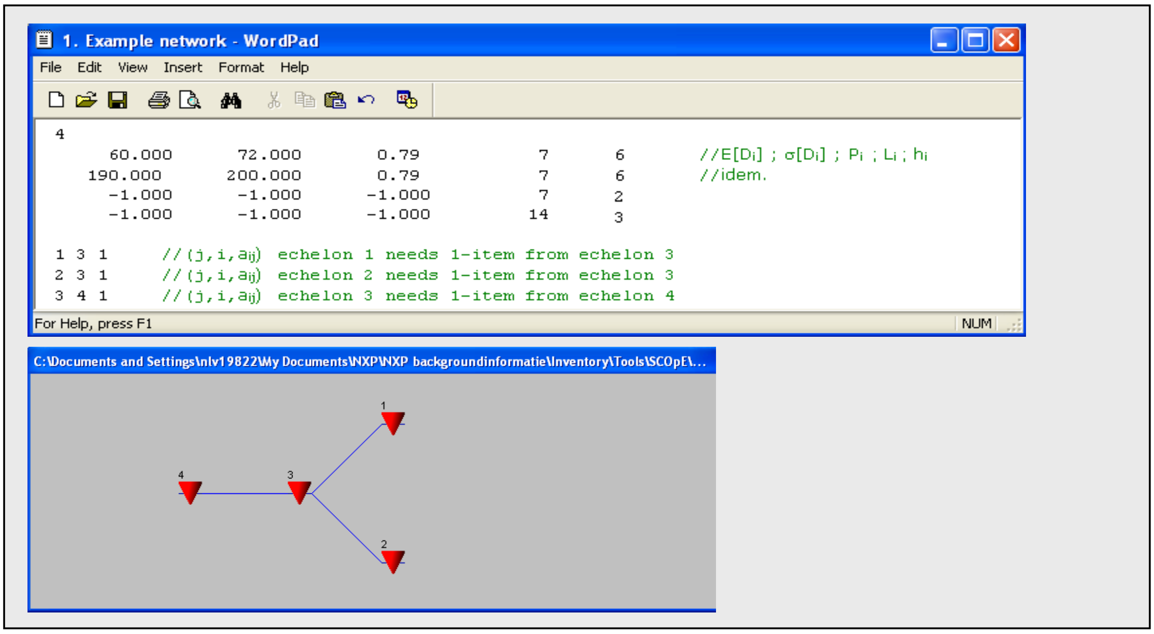
It is clear that the safety stock at a stock point equals SS= $k * \sigma_D * \sqrt{R+L}$, but we have to realize that this is not all stock in the system. We have to include the average pipeline stock, being approximately half of the replenishment order size that is consumed during a replenishment cycle: ½*R* μ_D . Hence the total average physical stock at a stockpoint will be (Silver *et al.*, 1998):

$$E[\text{inventory.on.hand}] = \frac{1}{2} * R * \mu_D + k * \sigma_D * \sqrt{R+L} + E[\text{back log}]$$

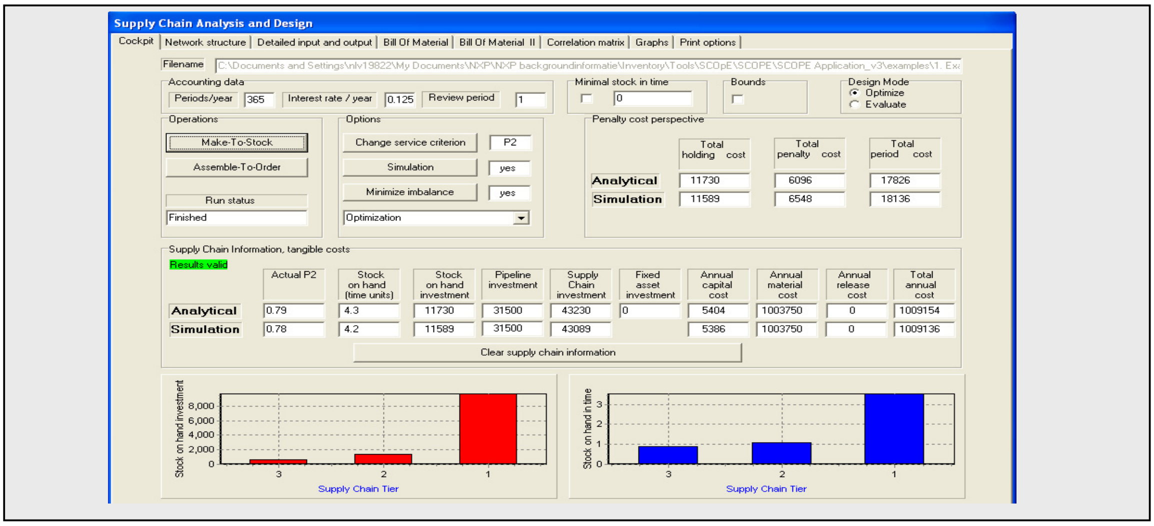
The reason of taking the E[backlog] into account while calculating the E[inventory on hand] is that otherwise you will get an underestimation of the calculated figure because of the fact that the inventory on hand is theoretically speaking above (no stockout) or below (stockout) zero just before a replenishment order arrives. In practice, this is respectively a positive number (no stockout) or 0 (in case there is a stock out) and hence we have to include the average back log to get a good representation of the expected inventory on hand. For a comparison of exact calculation methods we refer to Van der Heijden & De Kok (1998).

Appendix F: Snap-shots SCOpE

The input parameters related to the demand and supply side can be filled in by any editor (see figure below). For each item that is not an end-item (i.e. an intermediate item), $E[D_i]$, $\sigma[D_i]$ *and* P_i are set as –1. This example comprise a network of 4 stock locations of which location 1 and 2 faces a direct customer demand and hence can be seen as a CODP location



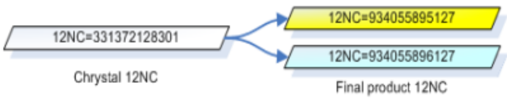
Given the network structure and the system settings, the screen as depicted below will appear in which the overall network performance is showed in tabular and graphical format. Detailed information related to the specific stock locations can be found in the detailed input and output tab and in the graphs tabs. The other tabs (Network Structure, Bill of Material II, Correlation matrix) are there to define the network structure under analysis. In the network structure tab the network structure can be build in a visualized way, instead of creating it via an editor as discussed above.

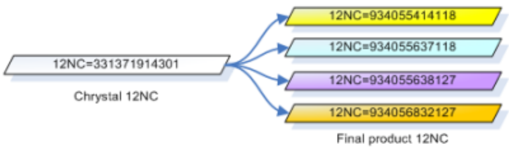


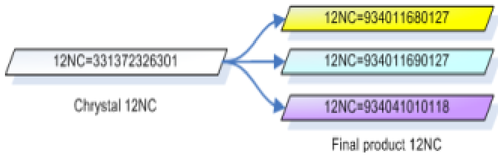
Appendix G: Overview selected Case studies

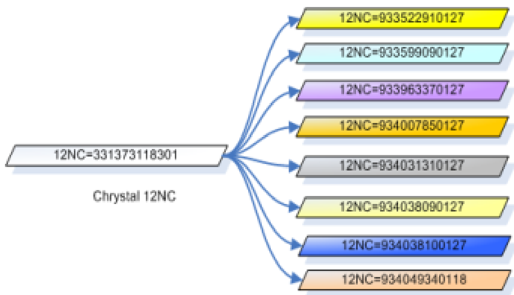
High AUTO PO (calculated over week 15-22 2007) indicates less Planner intervention and thus
1 Probability that there is an allocation is lower
2 Probability that customers are requesting orders with a LT lower than CODP LT to customer dock

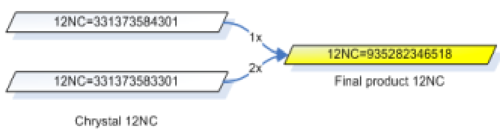
	X-tal	12NC	12NC Description	Customer Specific	Customers	CPs	Multi Die	Multi Source
Case 1	331372128301	934055895127	BYV29-600/SOD59/RAILH//	N	Multi	N	N	N
		934055896127	BYV29X-600/SOD113/RAILH//	N	Multi	Y	N	N
	R72							
	4TG = 9663							
	AUTO PO = 61%							
Case 2	331373484301	934003470215	2N7002/SOT23/REELLP//	N	Multi	Y	N	N
		934056996215	2N7002E/SOT23/REELLP//	N	Multi	Y	N	N
	R73	934056997215	2N7002F/SOT23/REELLP//	N	Multi	Y	N	N
	4TG = 9624	934058631215	2N7002/SOT23/REELLP//G	N	Multi	Y	N	N
	AUTO PO = 82%							
Case 3	331371914301	934055414118	55A/SOT404/REEL13//	N	Multi	Y	N	N
		934055637118	PSMN005-	N	Multi	N	N	N
	R73	934055638127	PSMN005-55P/SOT78/RAILH//	N	Multi	N	N	N
	4TG = 9653	934056832127	BUK9E06-55A/SOT226/RAILH//	Y	MITSUMI	N	N	N
	AUTO PO = 88%							
Case 4	331372326301	934011680127	BYV32E-150/SOT78/RAILH//	N	Multi	N	N	N
		934011690127	BYV32E-200/SOT78/RAILH//	N	Multi	Y	N	N
	R72	934041010118	BYV32EB-200/SOT404/REEL13//	N	Multi	Y	N	N
	4TG = 9662							
	AUTO PO = 48%							
Case 5	331373118301	933522910127	BT136-600E/SOT78/RAILH//	N	Multi	N	N	Y
		933599090127	BT136-800E/SOT78/RAILH//	N	Multi	N	N	Y
	R72	933963370127	BT134-600E/SOT82/RAILH//	N	Multi	N	N	N
	4TG = 9613	934007850127	BT134-800E/SOT82/RAILH//	N	Multi	N	N	N
	AUTO PO = 86%	934031310127	BT136-600E/SOT78/RAILH//L01	N	Multi	N	N	N
		934038090127	BT136X-600E/SOT186A/RAILH//	N	Multi	N	N	Y
		934038100127	BT136X-800E/SOT186A/RAILH//	N	Multi	N	N	Y
		934049340118	BT136S-800E/SOT428/REEL13//	N	Multi	N	N	N
Case 6	331373583301	935282346518	ON5423/HSSON14/REEL13DP//	Y	HELLA	N	Y	Y
	331373584301							
	R73							
	4TG = 4114							
	AUTO PO = 0%							











Appendix H: Description with validation results of case study no.1

An example of the validation phase with respect to the way of working will be explained by discussing case no.1. The supply chain can be visualized as given in Figure H.1. We can make the following observations:

- This is a two echelon network containing the Die bank and a IWH. Only the network upstream the CODP is modeled because the rest is order driven and hence no planned stock will occur. In reality, when the CODP is located at the Die bank, the products will of course flow through the same back-end factories and will be shipped via the IWH for packing and labeling issues.
- We have two end products (934055895127 & 934055896127) flowing form the same Die. All the customers that are placing orders for the first products (934055895127-yellow) have their CODP at the Die bank and hence all the demand can be aggregated. The demand for the second product (934055896127-blue) can be split up in three different buckets because of the different CODP settings among the customers. The CP is treated separately.
- Node 1,2,3,4 & 5 are actually the same location, namely the Die Bank, and hence the planned lead time between 3 and the dummy nodes (1,2,4 & 5) is 0. The reason for using dummy nodes is to be able to use SCOpE (cf. section 5.4).
- The value adding per echelon is depicted at the top of Figure H.1.

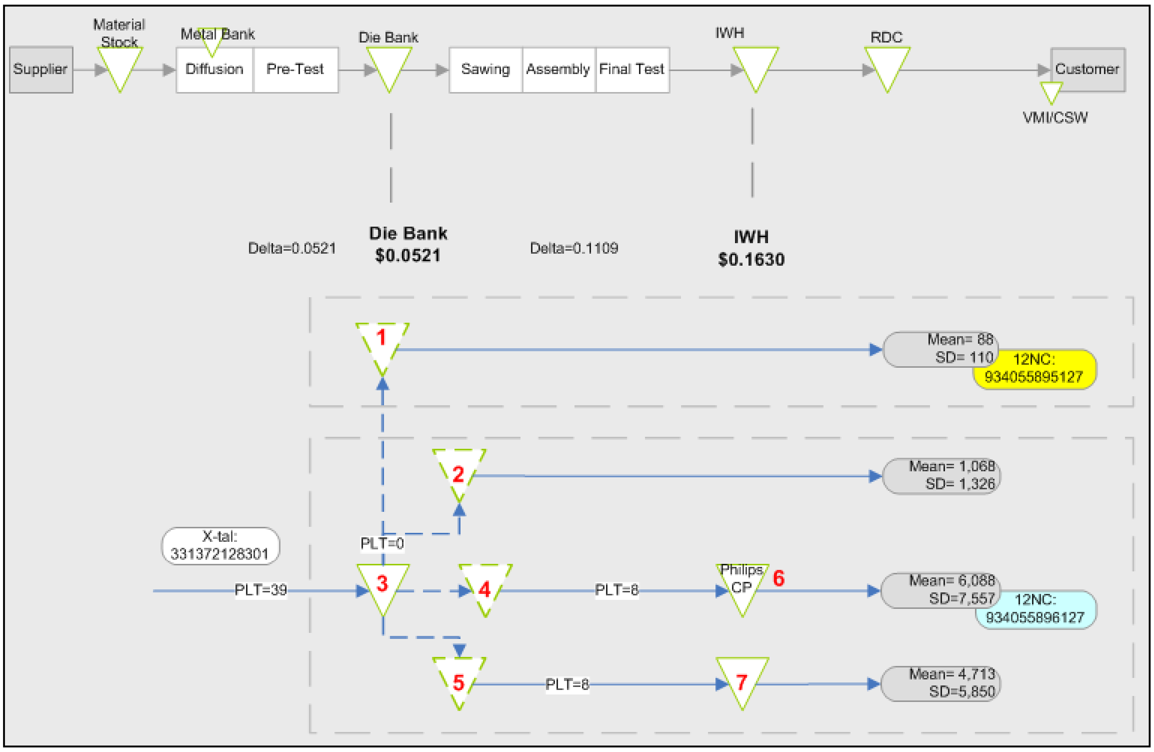


Figure H.1: Visualization of the supply chain of case study no.1.

After we modeled the supply chain in SCOpE, the other parameters can be filled in: $R_{front\text{-}end}$=7days; $R_{back\text{-}end}$=1day; Number of time units/year=365; WACC=12.5%; Evaluator mode; current safety stock settings; Make-to-Stock; safety stock at Die bank (node 1-5) is 4 weeks and safety stock at IWH (node 6 & 7) is 0.

A note is that the number of weeks safety stock is transformed to a quantity by multiplying the number of weeks coverage by the number of days per week and by the average total daily demand. This quantity is split over the dummy nodes based on the percentage of total die demand flowing via this dummy node. After using the evaluator mode we retrieve the results as graphically represented in Figure H.2 leading to the following observations:

- The actual perceived RLIP% in May is depicted at the right site of this figure and compared with the percentage as given by the SCOpE evaluator mode. We discussed these differences with the responsible planners and came to the following conclusions.
  - I. No difference.
  - II. Hardly any sales. Moreover, the order line that was delivered was requested within the lead time needed to flow from CODP to customer dock. Besids that, there was a yield problem.
    - Root cause # 2 & 5 ($RLIP_{evaluator} > RLIP_{actual}$)
  - III. Because there is no safety stock at the CODP, the evaluator shows a bad service. In practice, 93% can be reached because of the high pipeline stock (approx. 3wks in May caused by utilization and batching). Moreover, a CP gets priority when a CP-order is placed, leading to a relative high service level.
    - Root cause # 6 , 7 & 9 ($RLIP_{evaluator} < RLIP_{actual}$)
  - IV. High pipeline stock (approx. 3wks in May at this echelon for this product) caused by utilization in the front-end and batching in the back-end. Furthermore, analysis shows that over a longer period (wk 48-2006 till wk 17-2007), 81% of the order lines has a requested delivery later 14 days and hence enough to deliver from the Die Bank. That means that without safety stock at the CODP (IWH), the order can be met in most of the cases. The question that arise is whether the CODP location is correct for this group of customers.
    - Root cause # 6 , 7 & 9 ($RLIP_{evaluator} < RLIP_{actual}$)
  - V. The average service levels.

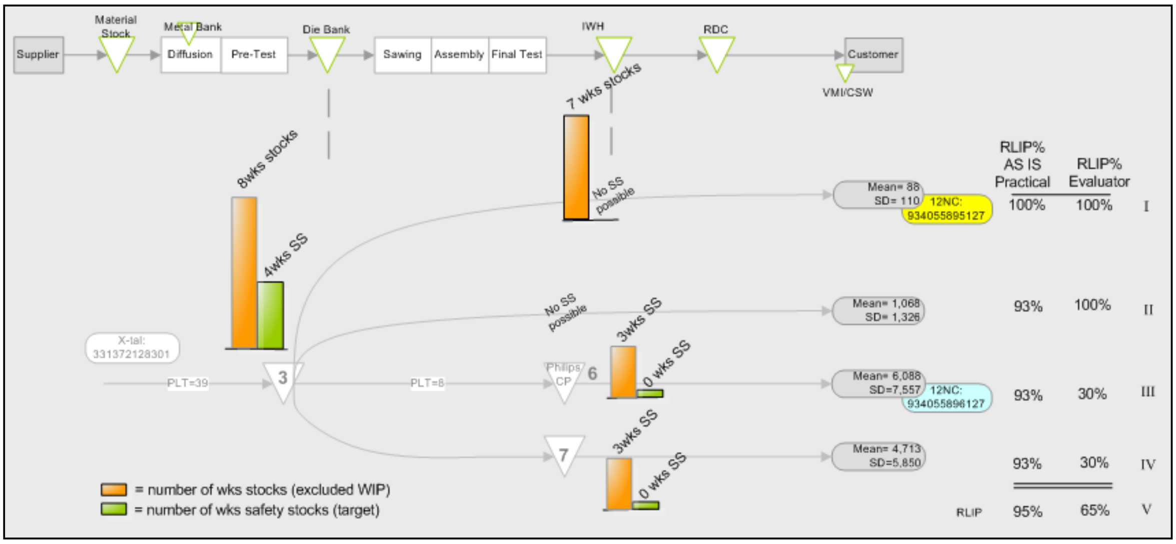
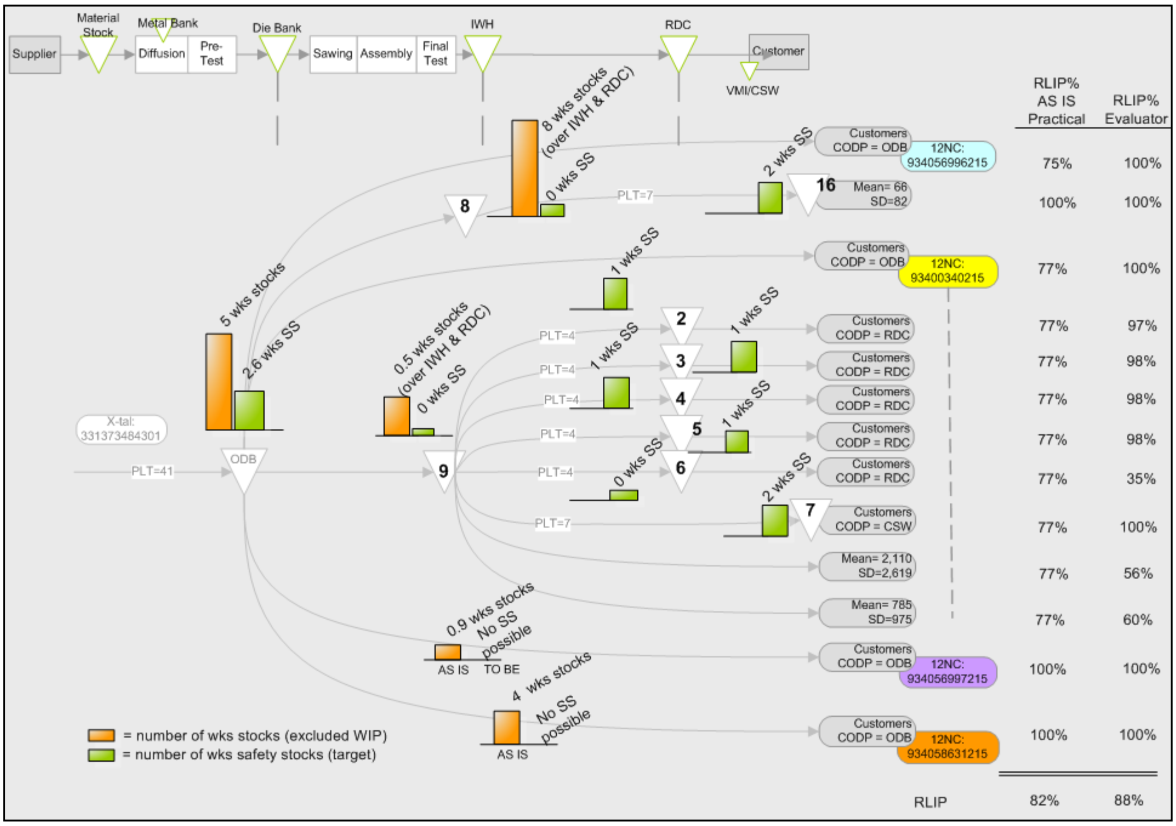


Figure H.2: Results of case study no.1 (May 2007) after using the evaluator mode of SCOpE.

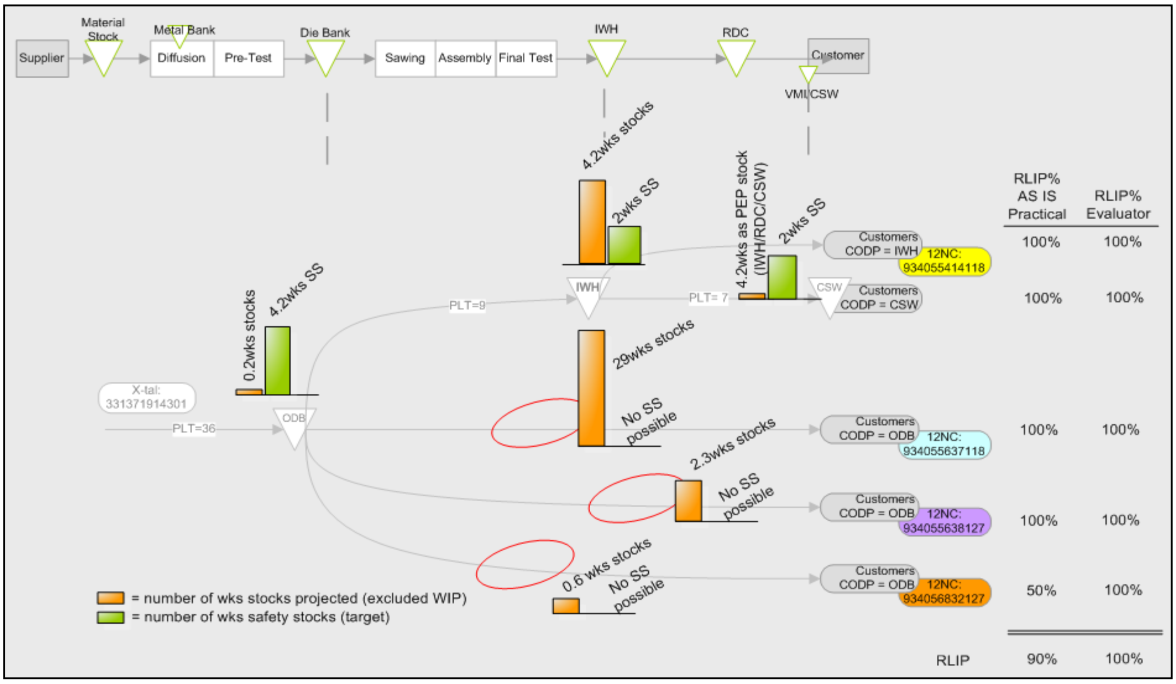
Appendix I: Overview of validation results case study no.2-5

In line with the previous description, all case studies are analyzed for the month May 2007.

Results case study no.2 (May 2007)

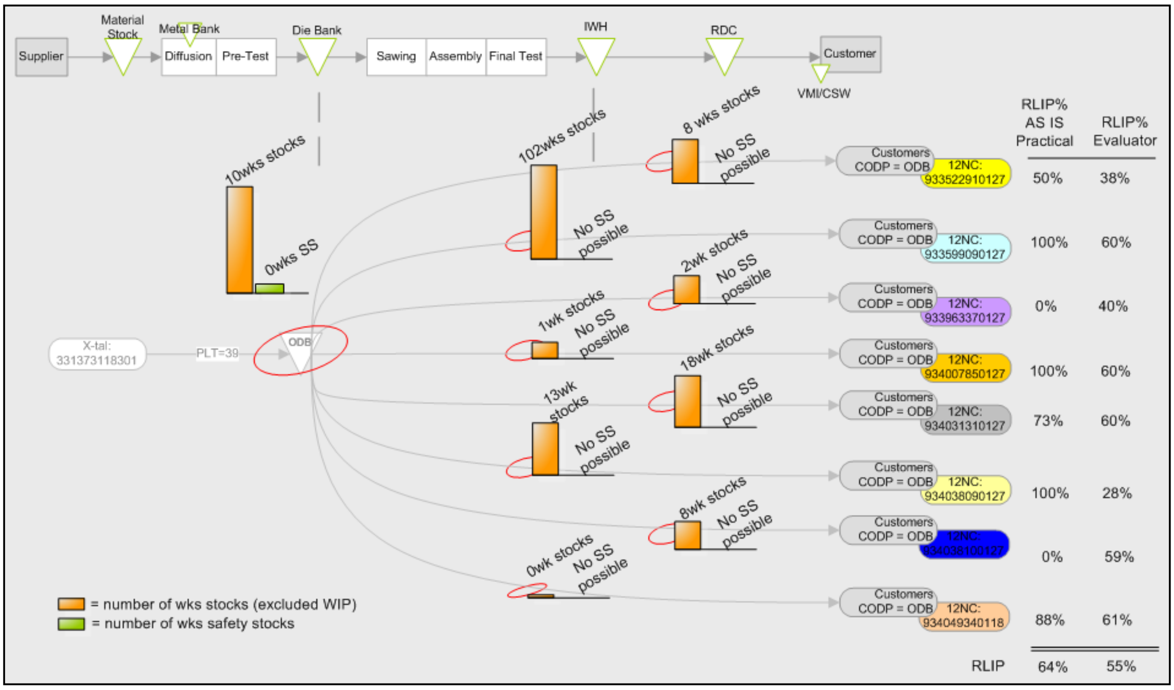


Results case study no.3 (May 2007)



Results case study no.4 (May 2007)

Results case study no.5 (May 2007)



Case study no.	Crystal	12NC	CODP	RLIP as is (May'07)	RLIP evaluator	RLIPevaluator > RLIPactual	RLIPevaluator < RLIPactual	Allocation 1	Order within LT 2	P2 vs RLIP 3	Under-FC 4	Lower yield 5	Increased utilization 6	High batch sizes 7	Over-FC 8	Long order LT 9	Order cancellations 10	Rounding quantities 11
Case 1	331372128301	934055895127	Assy start	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934055896127	Assy start	93%	100%	Yes	-	-	V	-	-	V	-	-	-	-	-	-
		"	MH	93%	30%	-	Yes	-	-	-	-	-	V	V	-	V	-	-
		"	MH	93%	30%	-	Yes	-	-	-	-	-	V	V	-	V	-	-
				95%	65%													
Case 2	331373484301	934003470215	Assy start	75%	100%	Yes	-	V	-	-	-	-	V	-	-	-	-	-
			CSW	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934056996215	Assy start	77%	100%	Yes	-	V	-	-	V	-	V	-	-	-	-	-
			RDC	77%	97%	Yes	-	-	-	-	V	V	-	-	-	-	-	-
			RDC-CP	77%	98%	Yes	-	-	-	-	V	V	-	-	-	-	-	-
			RDC-CP	77%	98%	Yes	-	-	-	-	V	V	-	-	-	-	-	-
			RDC-CP	77%	98%	Yes	-	-	-	-	V	V	-	-	-	-	-	-
			RDC-CP	77%	35%	-	Yes	-	-	-	V	V	-	-	-	V	-	-
			CSW	77%	100%	Yes	-	-	-	-	V	V	-	-	-	-	-	-
			MH-CP	77%	56%	-	Yes	-	V	-	-	-	-	-	V	V	-	-
			MH-CP	77%	60%	-	Yes	-	V	-	-	-	-	-	-	-	-	-
		934056997215	Assy start	100%	100%	N/A	N/A	V	-	-	-	-	V	-	-	-	-	-
		934058631215	Assy start	100%	100%	N/A	N/A	V	-	-	-	-	V	-	-	-	-	-
				82%	88%													
Case 3	331371914301	934055414118	MH-CP	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
			CSW-CP	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934055637118	Assy start	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934055638127	Assy start	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934056832127	Assy start	50%	100%	Yes	-	-	V	-	V	-	-	-	-	-	-	-
				90%	100%													
Case 4	331372326301	934011680127	Assy start	100%	100%	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-
		934011690127	Assy start	60%	100%	Yes	-	-	V	-	-	-	-	-	-	-	-	-
			MH-CP	60%	27%	-	Yes	-	-	-	-	-	-	V	V	-	-	-
		934041010118	Assy start	88%	100%	Yes	-	-	-	-	-	-	-	-	-	-	-	-
				77%	82%													
Case 5	331373118301	933522910127	Assy start	50%	38%	-	Yes	-	-	-	-	-	-	-	V	V	-	-
		933599090127	Assy start	100%	60%	-	Yes	-	-	-	-	-	V	-	V	-	-	-
		933963370127	Assy start	0%	40%	Yes	-	-	V	-	V	-	-	-	-	-	-	-
		934007850127	Assy start	100%	60%	-	Yes	-	-	-	-	-	-	-	V	-	-	-
		934031310127	Assy start	73%	60%	-	Yes	-	-	-	-	-	-	-	V	-	-	-
		934038090127	Assy start	100%	58%	-	Yes	-	-	-	-	-	-	-	V	V	-	-
		934038100127	Assy start	0%	59%	Yes	-	-	V	-	V	-	-	-	-	-	-	-
		934049340118	Assy start	88%	61%	-	Yes	-	-	-	-	-	-	-	V	-	-	-
				64%	55%													
Case 6	331373583301	935282346518	Assy start	Not able to model				-	-	-	-	-	-	-	-	-	-	-
	331373584301	935282346518	Assy start	Not able to model				-	-	-	-	-	-	-	-	-	-	-

Some notes:

- Root cause 3 is not analyzed in detail. This root cause is mentioned because we noticed the difference in section 4.2.2.
- Root cause 10&11 are not further investigated. According to planners they do occur but not that often or the effect is minimal.

Appendix J: SPSS output files

R72: Descriptive statistics (sort 2)

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Mature	70	1,584672	1,1460771	,4281	5,6569	,729100	1,184800	1,870750
Mature2	70	1,409618	,9142725	,4281	4,1616	,752750	1,075750	1,779252
Ramp_down	70	3,182456	1,4567411	,5841	5,6569	2,058452	2,845384	3,992654
Ramp_down2	70	3,322976	1,6381833	,7201	5,6569	1,894186	3,201176	4,862824
Ramp_up	70	2,714896	1,6247971	,5768	5,6569	1,299320	2,585380	3,910258
Ramp_up2	70	2,729516	1,6537960	,5768	5,6569	1,297370	2,155002	3,934955

R72: Descriptive Statistics (sort 3)

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Continuous	70	,895693	,3570752	,4268	1,8877	,654325	,789250	1,027050
Continuous2	70	,912779	,3670545	,4268	1,8877	,667200	,799100	1,052475
Discontinuous	70	2,136102	1,1269445	,9502	5,6569	1,318219	1,754545	2,561726
Discontinuous2	70	2,176098	1,1573416	,9502	5,6569	1,318219	1,834797	2,688086

R73: Descriptive Statistics (sort 2)

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Mature	70	1.177050	.8650387	.2630	3.9350	.642848	.852585	1.477457
Ramp_down	70	2.663353	1.5301261	.5717	5.6569	1.457448	2.476588	3.858760
Mature2	70	1.307340	1.0218903	.2933	5.6569	.613586	.923729	1.729611
Ramp_down2	70	2.620258	1.4526421	.5164	5.6569	1.612315	2.402706	3.565996
Ramp_up	70	2.110608	1.2170800	.5834	5.6569	1.276343	1.849411	2.711568
Ramp_up2	70	2.202468	1.3135262	.4847	5.6569	1.281862	1.803784	3.016531

R73: Test Statistics(c) (sort 2)

	Ramp_down - Mature	Ramp_up - Mature	Ramp_up - Ramp_down	Ramp_down2 - Mature2	Ramp_up2 - Mature2	Ramp_up2 - Ramp_down2
Z	-5.445(a)	-5.094(a)	-2.245(b)	-5.311(a)	-4.266(a)	-1.706(b)
Asymp. Sig. (2-tailed)	.000	.000	.025	.000	.000	.088

a Based on negative ranks.
b Based on positive ranks.
c Wilcoxon Signed Ranks Test

R73: Descriptive Statistics (sort 3)

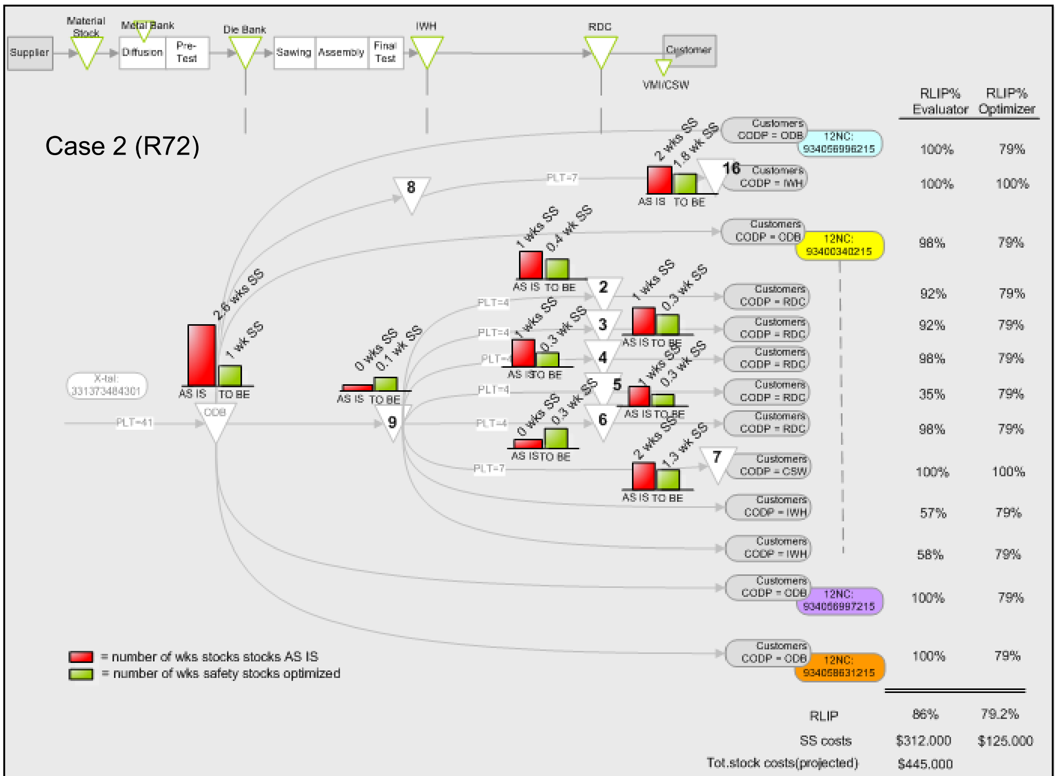
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Continuous	70	.736540	.3109902	.2106	1.5700	.462259	.657797	.967135
Continuous2	70	.766127	.3212965	.2630	1.8900	.496437	.661639	.933135
Discontinuous	70	2.092662	1.0134973	.8849	5.6569	1.310090	1.636428	2.690452
Discontinuous2	70	1.992071	.9613219	.8823	5.6569	1.286458	1.612643	2.516031

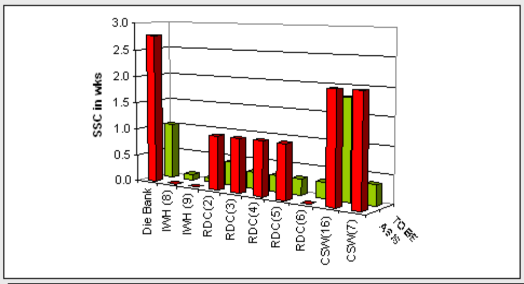
R73: Test Statistics(b) (sort 3)

	Discontinuous - Continuous	Discontinuous2 - Continuous2
Z	-7.236(a)	-7.236(a)
Asymp. Sig. (2-tailed)	.000	.000

a Based on negative ranks. b Wilcoxon Signed Ranks Test

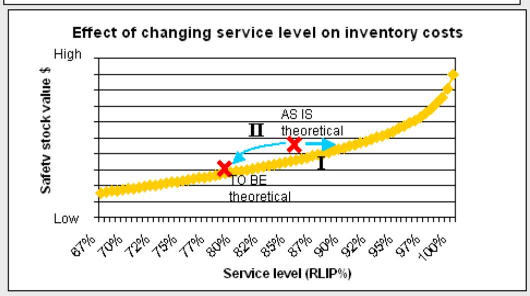
Appendix K: Case study results





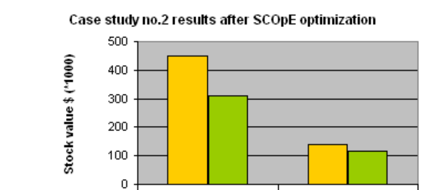
Safety stock proposals:

Die Bank	2.6 weeks	-->	1 week
IWH(8)	0 weeks	-->	0.1 week
IWH(9)	0 weeks	-->	0.1 week
RDC(2)	1 week	-->	0.4 week
RDC(3)	1 week	-->	0.3 week
RDC(4)	1 week	-->	0.3 week
RDC(5)	1 week	-->	0.3 week
RDC(6)	0 weeks	-->	0.3 week
CSW(16)	2 weeks	-->	1.8 week
CSW(7)	2 weeks	-->	1.3 week



I: The actual perceived service in practice can be higher because of the high projected inventory levels. These are caused by the root causes as mentioned in CH6.

II: Comparison of AS IS situation with SCOpE Optimizer
Input = the network and actual demand
Output = the optimal safety stock settings



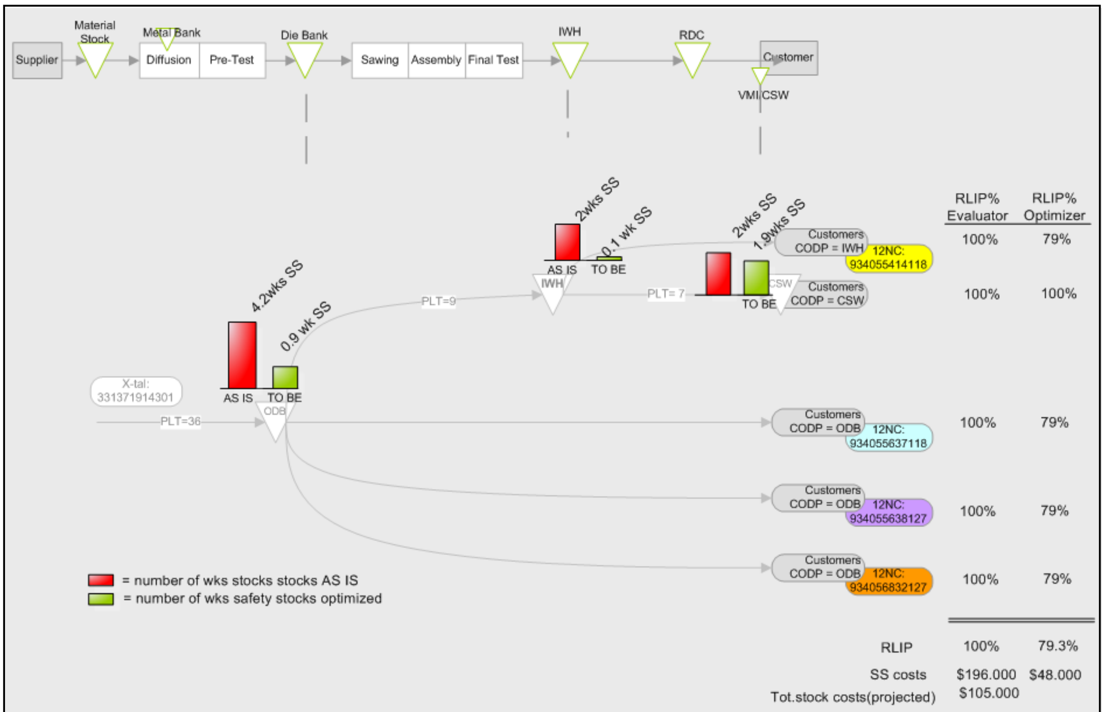
	AS IS	TO BE
Tot.av.inventory (excl WIP)	450	140
Safety Stocks	312	117

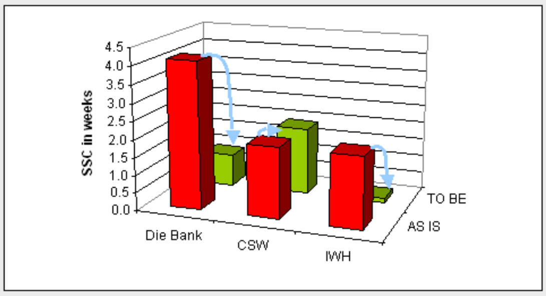
Case study #2 -June'07

Objective:
> Optimize inventory settings over network.

Results:
> Shift inventory partly down stream.
> 60% reduction of SS ($).
> 65% reduction of total average inventory should be possible.
> Decreased service level 86% --> 79%, but more stable over 12NCs

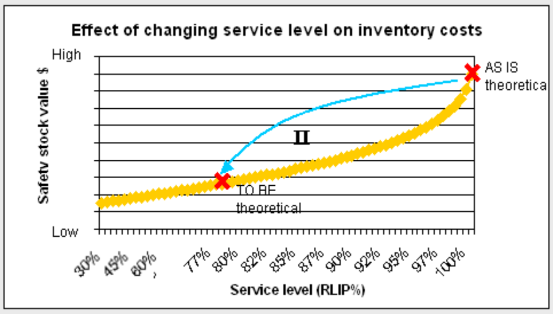
Case 3 (R73)



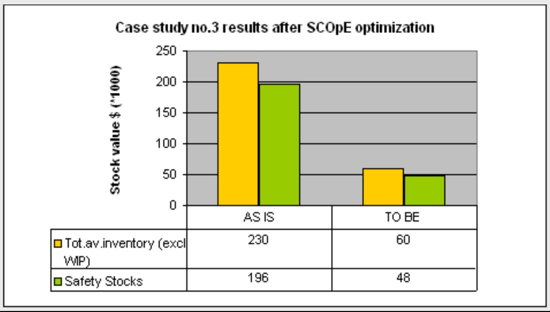


Safety stock proposals:

Die Bank	4.2 weeks -->	1 week
CSW	2 weeks -->	1.8 weeks
IWH	2 weeks -->	0.1 weeks



II: Comparison of AS IS evaluated situation with SCOpE Optimizer
Input = the network and actual demand
Output = the optimal safety stock settings

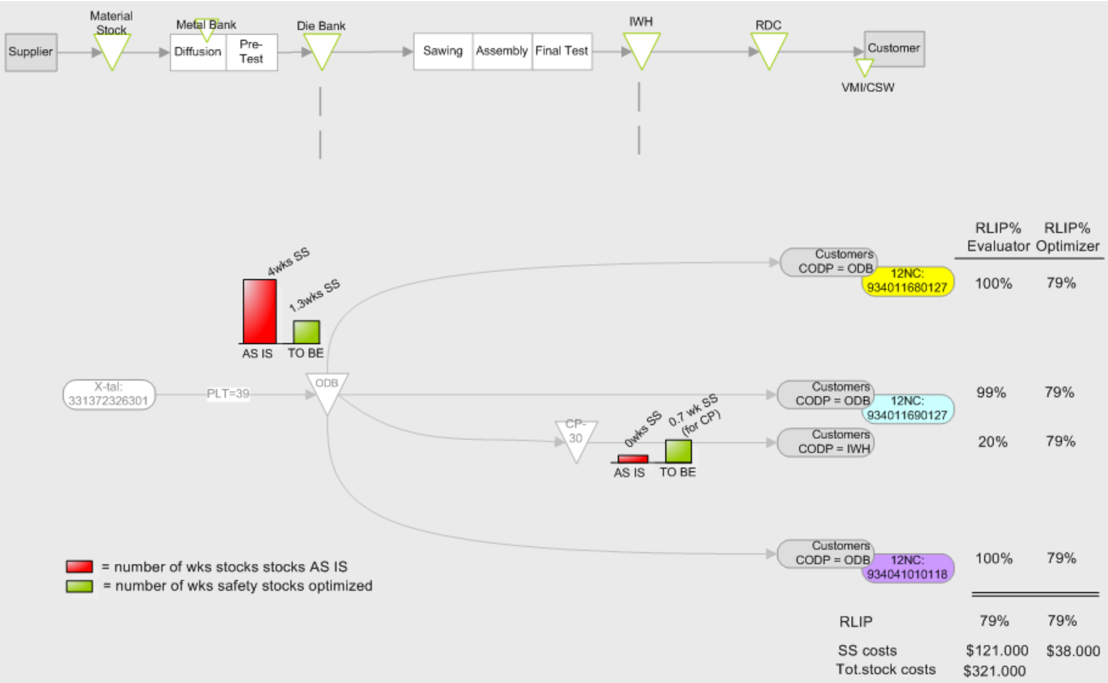


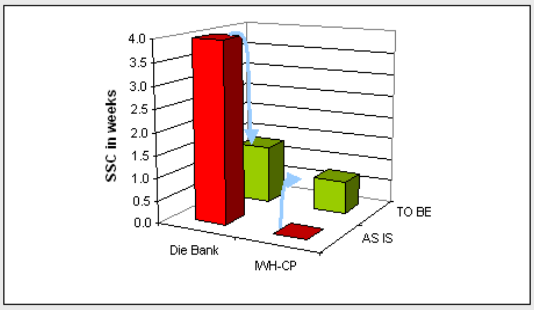
Case study #3 -June'07

Objective:
> Optimize inventory settings over network.

Results:
> Settings are too high.
> 75% reduction of SS ($).
> 75% reduction of total average inventory should be possible.
> Decreased service level 100% --> 79%

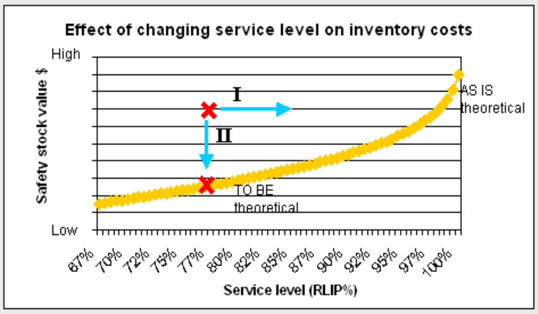
Case 4: (R72)





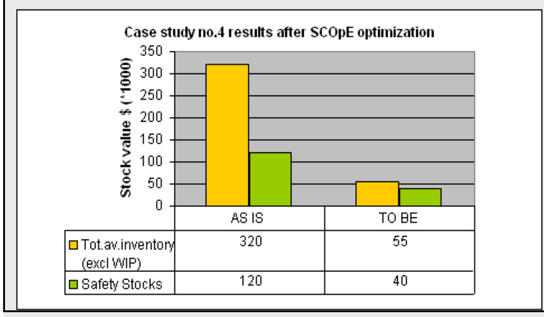
Safety stock proposals:

Die Bank	4 weeks --> 1.3 weeks
IWH-CP	0 weeks --> 0.7 weeks



I: The actual perceived service in practice can be higher because of the high projected inventory levels. These are caused by the root causes as mentioned in CH6.

II: Comparison of AS IS situation with SCOpE Optimizer
Input = the network and actual demand
Output = the optimal safety stock settings

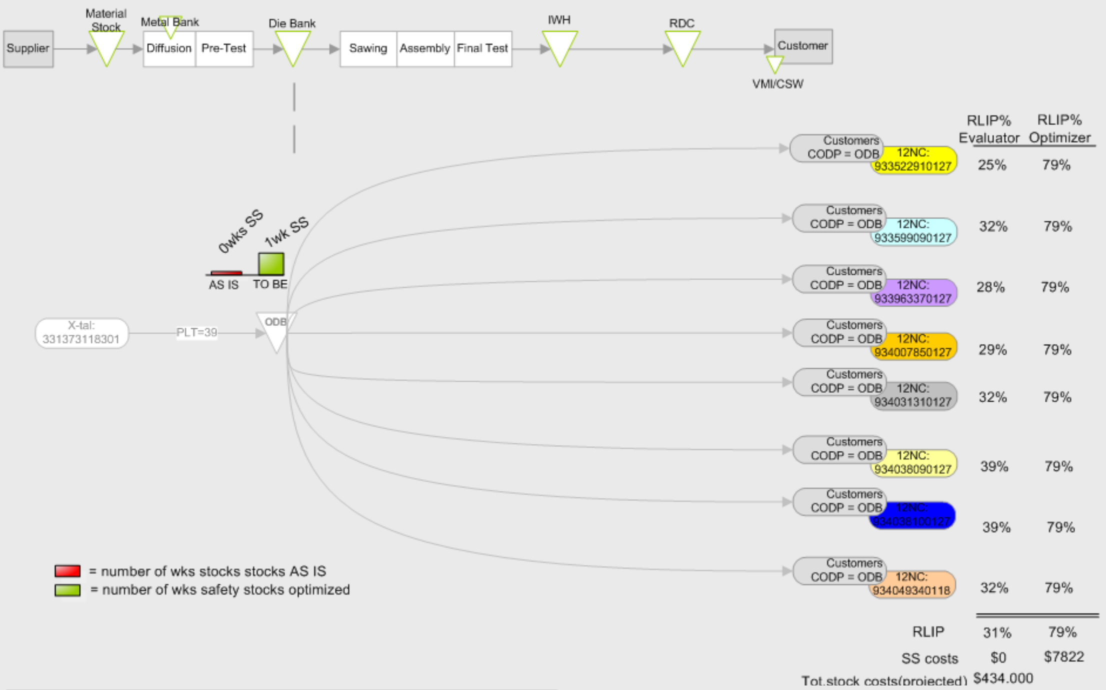


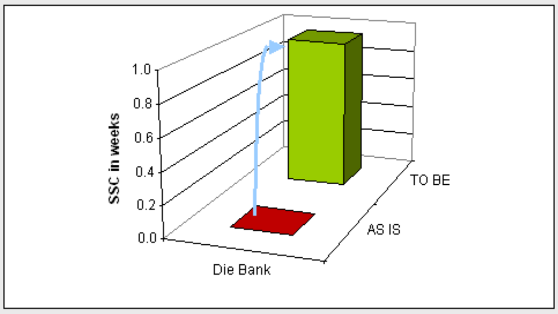
Case study #4 -June'07

Objective:
> Optimize inventory settings over network.

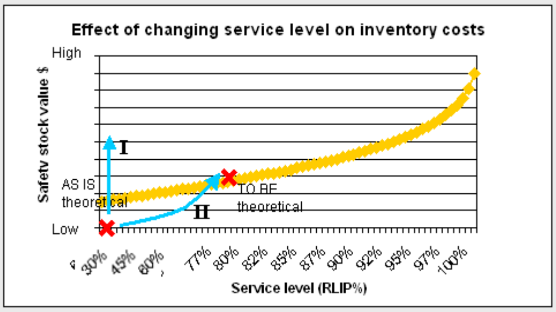
Results:
> Shift inventory partly down stream.
> 65% reduction of SS ($).
> 80% reduction of total average inventory should be possible.
> Increased service level possible 79% --> 79%, but more stable

Case 5 (R72)



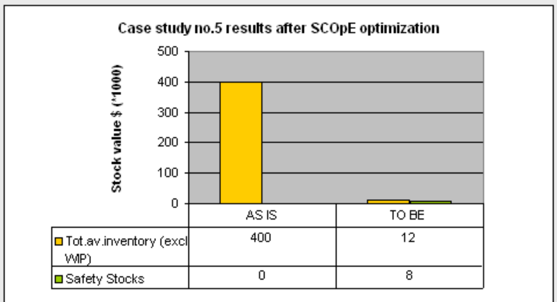


Safety stock proposals:
Die Bank 0 weeks --> 1 week



I: The actual perceived service in practice can be higher because of the high projected inventory levels. These are caused by the root causes as mentioned in CH6.

II: Comparison of AS IS situation with SCOpE Optimizer
Input = the network and actual demand
Output = the optimal safety stock settings



Case study #5 -June'07

Objective:
> Optimize inventory settings over network.

Results:
> Increase safety stock settings
> Increase of SS ($).
> 90% reduction of total average inventory should be possible.
> Increased service level possible 31% --> 79%

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